A Review of Baits and Bait Delivery Systems for Free-Ranging Carnivores and Ungulates

By Samuel B. Linhart, Andreas Kappeler, and Lamar A. Windberg

Abstract: Baits and bait delivery systems have been described for orally administering a variety of chemicals and biologicals to selected carnivores and ungulates. Development has varied from species for which bait preferences and means of distributing oral contraceptives have not yet been determined even on a limited scale (e.g., white-tailed deer) to cooperative, multicountry programs involving the annual distribution of millions of mass-produced oral rabies vaccine baits (e.g., red foxes in Europe). Much of the technical literature on the subject has appeared in sometimes obscure sources encompassing such fields as medical epidemiology, wildlife diseases, animal behavior, applied ecology, flavor chemistry, furbearer trapping techniques (lures and baits), and wildlife management. To date, there has been no unified summary of the available information for the various species, whether the objectives were the application of contraceptives, toxicants, or vaccines. Techniques employed both in the past and at present will be of interest to wildlife biologists, public health officials, and other scientists seeking to develop contraception as a management technique for wildlife.

Keywords: baits, bait delivery techniques, baiting efficacy, carnivores, oral contraceptives, oral rabies vaccines, toxicants, ungulates

Interest in controlling wildlife populations with oral contraceptives began in the early 1960's, but the approach was abandoned due to a lack of safe, effective, long-lasting drugs and efficacious means of delivery. In the United States, such efforts were directed primarily at the coyote *(Canis latrans)* in the West because of its depredations upon livestock, and at the red fox *(Vulpes vulpes)* in the Northeast because, at the time, this species was the principal vector of rabies. Limited effort was later directed at the raccoon *(Procyon lotor)* and at the striped skunk *(Mephitis mephitis)* in the upper Midwest because they also were widely implicated as carriers of the disease. Since these early efforts, social, regulatory, and technological changes have been profound. As a result, investigators studying wildlife contraception are employing much more sophisticated approaches to the problem. Nonetheless, then as now, developing methods for delivering orally effective compounds to intended species by safe and selective techniques at a reasonable cost remains a major challenge.

Oral delivery of contraceptives is essential for free-ranging wild species because, unlike domestic animals, capture and restraint for parenteral administration of drugs are both impractical and costly. Moreover, delivery of biologically active compounds affecting reproduction is more complicated than was true for the bait-delivered, stable, and relatively inert chemical toxicants so widely used in the past. For example, oral contraceptives and immunogens may lose potency when exposed over time to ambient temperatures or when placed in direct contact with organic bait materials. If this approach is to succeed, such constraints—along with public concern about possible adverse environmental impacts and the need for definitive data to support claims of efficacy, safety, and licensure—will require those implementing it to have expertise in a number of diverse disciplines.

Developing contraception for wildlife will require a series of steps depending in large part upon what is currently known about delivery techniques for a given species. Wildlife professionals need baits, grains, or pelleted formulations that will be readily and consistently ingested by the intended species. For some animals, success may require the use of olfactory attractants to enhance bait discovery or determination of the best means of concentrating animals by pre-treatment supplemental feeding. Contraceptives must be incorporated into baits such that their stability and delivery to the site(s) of uptake within the animal is assured. It will be necessary to determine how well target animals discover and consume baits, the extent to which baits are removed by nontarget species, and if the latter are adversely affected. Delivery system development will require information about the feeding behavior, reproductive characteristics, ecology, and population dynamics of target species, and how baiting efficacy may change seasonally, geographically, or with the availability of naturally occurring foods. Field trials must determine selective bait-delivery methods and the minimum density of treated bait or grain (i.e., quantity/km^2) required to suppress reproduction to desired levels. Efficient and cost-effective methods for mass production of treated baits or grains must be devised; and, finally, cost–benefit studies will be needed to justify widespread application.

Literature describing the field delivery of oral contraceptives is almost completely lacking. However, many published reports deal with baits and bait delivery systems for distributing toxicants (e.g., Debbie 1991) and oral rabies vaccines (e.g., World Health Organization 1990a), and for this reason they have been extensively reviewed and summarized. We used Wildlife Review (U.S. Department of the Interior, National Biological Service, Fort Collins, CO 80525–5589, U.S.A.), the National Wildlife Research Center Predator Literature Database (U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control, National Wildlife Research Center, Fort Collins, CO 80525, U.S.A.), Wildlife Worldwide (National Information Service Corporation, Baltimore, MD 21218, U.S.A.), and Current Contents (Institute for Science Information, Philadelphia, PA 19104, U.S.A.) as literature sources. In addition, we have collectively investigated delivery methodology for many years, have accumulated the literature on the subject, and have contact with colleagues and collaborators doing such work. Coauthor Kappeler also contacted bait manufacturers for information about their laboratory and field tests, the physical properties of baits, and the numbers produced commercially. The individual species accounts that follow vary in length because they reflect the current status or "state of the art" for each species and associated reports and publications. The taxonomic source for scientific names was Wilson and Reeder (1993).

Red Fox *(Vulpes vulpes)*

Baits distributed for red foxes have served two major purposes: population control through either poisoning or inhibition of reproduction and oral vaccination against rabies. Although both poison baits and baits containing antifertility agents received some attention in the 1950's and 1960's, and again in recent years, their impact was minor compared to the effects of the European and Canadian oral rabies vaccination programs on the prevalence and distribution of the disease. In Europe alone, 74 million baits containing oral rabies vaccine had been distributed by the end of 1994, a few smaller trials in former member states of the Soviet Union not included (K. Stöhr, pers. comm.). The Canadian program in Ontario added another 4.5 million baits (1989–94). Because baits and baiting strategies for red foxes have varied widely, we elected to divide the red fox section in this review according to objectives, with additional subsections within the discussion on oral immunization.

Poisoning

Poisoning has been used primarily in North America during the 1950's and 1960's to reduce wildlife rabies vectors (for a review, see Debbie 1991). The most massive campaign was carried out in Alberta, Canada, prompted by an outbreak of rabies in 1952 (Ballantyne and O'Donoghue 1954). Fat from various sources (beef, pork, sheep, horse, bear) was melted, supplemented with paraffin and beeswax for summer use (higher melting temperature), and poured into small paper cups. Strychnine cubes or cyanide-filled capsules were inserted before the fat (15–20 g) solidified. Boiled eggs inoculated with strychnine or canned dog food rolled in birch bark also served as baits. These baits were distributed by trappers who used an unidentified scent to increase bait attractiveness, put out "draw baits" such as rabbit carcasses or pieces of meat, or inserted a feather into baits to make them more visible. It was estimated that more than 90,000 carnivores, of which 50,000 were foxes, succumbed to the 429,000 poison baits distributed in forest areas alone between October 1952 and March 1954 (Ballantyne and O'Donoghue 1954). The depopulation program may be one of the reasons why only two cases of rabies were recorded in Alberta between summer 1956 and 1971, when rabies in striped skunks became apparent (Rosatte et al. 1986).

Similarly, in Tennessee, U.S.A., more than 9,000 bait stations were operated at a density of 0.86/km^2 and replenished daily for 5 to 11 consecutive nights (Lewis 1968). Beef suet baits containing strychnine were used, and 38 percent of them were removed. Foxes accounted for 43 percent of the baits taken, dogs *(Canis lupus familiaris)* for 29 percent, domestic cats *(Felis catus)* and scavenging birds for 4 percent each, and various other animals for 7 percent. Thirteen percent of the baits had been removed by humans. Nontarget species' bait uptake or removal was reduced when baits were distributed by landowners on their own properties. However, Lewis (1968) questioned the effectiveness of the program. Carcass searches were not conducted, and bait disappearance rates did not usually diminish over the baiting period, suggesting that the effort had only a small effect on local populations of potential bait consumers. An evaluation of the number of rabies cases per county before and after baiting was inconclusive.

Denmark has repeatedly stopped the spread of rabies in foxes by applying strict control measures (gassing, shooting, poisoning) in a 60-km-wide zone along the country's southern border with Germany. Following the distribution of strychnine baits (chicken necks, piglets, eggs) in January to March of 1979 and 1980, the carcasses of 482 red foxes, 498 martens *(Martes* sp.), 12 European badgers *(Meles meles)*, and 4 dogs were recovered (Westergaard 1982). The number of rabies cases sharply declined in 1980, and the country has remained free of terrestrial rabies since 1982 (Gaede 1992).

Although rabies in terrestrial mammals is absent from Great Britain, that Nation has developed control strategies in the event an outbreak should occur. The policy aims at containing the disease locally by destroying the vector population with poison baits. After prebaiting target areas for several days with untreated chicken-head baits, these would be replaced by day-old chickens containing 50 mg of strychnine sulphate (Meldrum 1988). Trewhella et al. (1991) tested the proposed control method in a well-described urban fox population in Bristol using untreated baits and baits containing iophenoxic acid (IA) as a biomarker (Larson et al. 1981). Baits of mechanically recovered chicken meat were stiffened with a 2.5-percent gelatin solution to make them sufficiently firm while keeping them friable enough to prevent foxes from carrying them away and caching them. Baits were buried 5 cm deep at a density of 1.6–3 per fox (32 baits/km^2) and checked and replenished daily for 7 days. Seasonal bait disappearance rates increased from 27 percent in February to 56 percent in fall, with considerable variation between habitat types. It was estimated that 85 percent of baits were taken by foxes and the remainder by dogs. When the number of baits was doubled, the disappearance rates remained constant, suggesting that either the same number of foxes were taking more baits, or that more foxes had access to baits. Given the comparatively low percentage of foxes positive for IA (35 percent of adults and 17 percent of cubs after a summer trial, 29 percent of adults and 23 percent of subadults after a winter trial), Trewhella et al. (1991) concluded that the control strategy was unlikely to contain an outbreak of rabies in a local fox population.

In Australia, aerial distribution of brisket fat baits containing strychnine started in the late 1940's and may have resulted in the local and temporary reduction of predators that prey on livestock and the native fauna (wild dogs, dingoes *[Canis lupus]*, red foxes) (Tomlinson 1954).

Compound 1080 (sodium monofluoroacetate) has since replaced strychnine as the poison of choice and is injected into pieces of meat or offal. Foxes are known to remove a considerable proportion of such baits (McIlroy et al. 1986a), and fox control has received more attention in recent years. Thompson and Fleming (1994) evaluated the effect of poisoned meat baits (6 mg of 1080 in 100 g of fresh meat) placed at 120 tracking stations in each of 2 plots of 10 km^2. Even though only 8–10 percent of all poison baits were removed by foxes, population reduction of 66 and 73 percent was achieved in the 2 plots, respectively, as estimated from assessments before and after baiting with tracking stations containing a different, nontoxic bait. Prebaiting and daily replenishment of baits during 10 days may have maximized the effect of the poisoning campaign to an extent not commonly achieved.

D–K9, a new, storable fox bait, was tested in New South Wales in 1992. It consisted of a 35-mm-long, green, shelf-stable sausage containing meat, lure chemicals, and a tablet of 1080 (Fleming et al.

1992b). The new bait was removed by foxes at about the same rate (23 percent) as fowl heads (25 percent), but considerably better than meat (10 percent) and liver baits (12 percent).

Another Compound 1080-based bait became commercially available in 1992. Foxoff® was developed by a private company (Applied Biotechnologies Ltd., 52–60 Export Drive, Brooklyn, Victoria, 3025 Australia) and the Department of Conservation and Natural Resources, Victoria. The bait, a rectangular tablet of either 35 g or 60 g, is semisoft and meat based and contains stabilizers and binders as well as 3 mg of 1080 (L. D. Staples, pers. comm.). To minimize the risk of nontarget uptake, individual landholders bury the baits 6–10 cm deep, preferably every 50–200 m along tracks or fences. The recommended density is 5–10 baits/km^2 in two campaigns per year.

In eight different trials, Foxoff was compared with one or two other 1080 bait types that were made locally of beef meat, bovine liver (fresh and cooked), horsemeat, mutton, lamb tongue, and chicken heads (Applied Biotechnologies 1994). In most trials for which the consuming species could be identified (based on tracks on sand pads), more than 90 percent of all baits had been taken by canids, mainly foxes. Uptake by nontarget species was rare (dogs, cats, pigs, birds) and independent of bait type, suggesting that the method of bait distribution (burying) rather than the bait itself accounted for the species specificity. In five out of eight trials, all baits tested performed equally well. On one occasion Foxoff was superior to both chicken heads and mutton but was outperformed by cooked liver and by horsemeat in one trial each. Typically, the number of baits taken per night dropped to very low levels within 2–3 weeks, suggesting a substantial reduction of the local fox population (Applied Biotechnologies 1994).

Reproduction Control

The application of antifertility agents as a less invasive method of controlling rabies vectors received considerable attention in the early 1960's. Linhart (1964) tested eight different bait types to evaluate a suitable vehicle for the synthetic hormone diethylstilbestrol (DES): limburger cheese cubes, fried beef fat cubes, crackling mixture (mixture of fried cheese, fish, suet, bacon), raw venison cubes, and four types of rendered tallow baits (mutton, beef, pork) that were used either directly or topped with an attractant (cheese, commercial honey bait mixture that included musk, beaver *[Castor canadensis]* casters, muskrat *[Ondatra zibethicus]* anal glands, spices, honey). For field placement, a feather was inserted into each bait to make it more visible in the snow. Two bait types were put out at each of a series of bait stations that were maintained and regularly checked for 2–3 months in winter. Foxes consumed 45 percent of all baits, dogs took 30 percent, and crows *(Corvus brachyrhynchos)*, 16 percent. These pairwise comparisons did not reveal a single bait type to be superior in attractivity or species specificity (Linhart 1964).

In North Dakota, U.S.A., a bait made of ground pork fat coated with granulated sugar and containing DES as well as tetracycline as a biomarker, was distributed to a population of red foxes (Allen 1982). Even though 70–75 percent of the foxes had taken bait, as determined by tetracycline marks in mandibular bones, DES had no effect on fox reproductive performance.

Goretzki et al. (1979) studied the potential of a 2- × 4-cm cylindrical tallow bait as a vehicle for antifertility agents and assessed bait uptake by incorporating radioactive iron (Fe-59) into each bait. Baits were placed in groups of four near dens and on fox crossings at an overall bait density of 3 baits/km^2. Measurement of radioactivity of liver, spleen, and kidney samples of killed foxes showed bait uptake to be 68 percent (n = 40).

Recently, the Commonwealth Scientific and Industrial Research Organization (known universally by its acronym, CSIRO) Division of Wildlife and Ecology in Australia started a project to develop an immunocontraceptive vaccine for fox control, whereby a fox sperm-specific antigen would either be vectored in a vaccinia recombinant vaccine or as a non-viral vectored antigen encapsulated in microsphere particles. In both instances, the vaccine would have to be delivered by bait; corresponding studies are currently being undertaken (World Health Organization 1993a).

Oral Vaccination Against Rabies

It became apparent in the early 1970's that red foxes could be immunized against rabies using live attenuated vaccine given by direct oral instillation (Baer et al. 1971, Debbie et al. 1972, Mayr et al. 1972, Black and Lawson 1973). This early work has resulted in widespread application of vaccine baits in Europe and North America. The various baits that have been developed, their field evaluation, and the different baiting strategies that have been utilized are reviewed below.

Baits

The first successful immunizations of captive foxes with baits were done with vaccine inoculated into eggs; vaccine-impregnated dog biscuits coated with a mixture of tallow, paraffin, and sardine oil; and a commercial smoked beef sausage containing a plastic tube filled with vaccine (Debbie 1974, Winkler et al. 1975, Winkler and Baer 1976). Winkler et al. (1975) also tested placebo dog biscuits in the field (table 1), while eggs were abandoned as a delivery device for oral vaccine out of concern about foxes caching rather than consuming them. In Europe, baits based on ground meat and chicken heads were field-tested with good results (Wandeler et al. 1975, Manz 1976), and the latter were used in many studies aimed at orally immunizing captive foxes (e.g., Dubreuil et al. 1979, Häfliger et al. 1982). In Canada, Black and Lawson (1980) immunized 44–80 percent of captive foxes with vaccine contained in plastic pouches covered with fish oil. In later trials, a polyurethane sponge, coated with several layers of a beef fat and wax mixture and injected with 14 mL of vaccine, successfully immunized a high proportion of captive foxes (Lawson et al. 1987). The above bait was developed by the Ontario Ministry of Natural Resources, which has tested numerous bait types in captivity and in the field (Johnston and Voigt 1982, Bachmann et al. 1990, Johnston et al. this volume). Unfortunately, as with many other bait tests conducted in Europe, the results of most tests were restricted to internal reports; only limited data were ever published (see Ruette [1993] for a review of French and Canadian internal reports and Winkler [1992] and Winkler and Bögel [1992] for reviews of the development of oral rabies vaccination techniques).

The majority of the early European studies that used vaccine-laden baits emphasized vaccine performance rather than bait efficacy even though a bait that effectively delivers the vaccine to the target organ is a prerequisite for successful oral immunization (Wandeler 1991). Nevertheless, with about 74 million baits distributed in Europe by the end of 1994 (K. Stöhr, pers. comm.), more data on bait development might have been expected. However, excepting the use of chicken heads, all other baits distributed in Europe have been manufactured by or in close collaboration with companies pursuing a commercial interest. The manner in which oral vaccination campaigns evolved may therefore account for both the low number of field tests conducted with placebo baits and the lack of published data on such trials.

Before the first field trial with vaccine baits was initiated in Switzerland, chicken heads were tested in the laboratory and field (Wandeler et al. 1975). A vaccine container made from a polyvinylchloride (PVC) film and aluminum foil was developed and, when fixed under the scalp of a chicken head, was proven to deliver vaccine into the oral cavity of a fox chewing this bait (Häfliger et al. 1982). In October 1978 in the Swiss Alps, this system underwent its first field test in a mountain valley in the Canton of Valais, which was threatened by an advancing front of rabies. Field application of vaccine baits was subsequently repeated twice a year. Following the first campaigns, about 60 percent of foxes collected in the vaccinated area were found positive for the biomarker tetracycline that had been injected into each bait, and within a year epidemiologic data suggested that the treatment was successful (Steck et al. 1982).

Given the obvious success in the Canton of Valais, there was little incentive to investigate alternative baits or baiting strategies when other cantons began using this new approach to rabies control. Chicken-head baits were subsequently used with success in Germany when campaigns were begun in that country in 1983. However, as Germany's rabies situation required that very large areas be treated, the

Table 1. Disappearance rates of baits used in or intended for use in oral vaccination campaigns of red foxes

Bait type	Location[1]	Time	Bait density (no./km²)	No. of baits placed	Percent baits disappeared after 1d	2d	3d	4d	6d	7d	8d	9d	10d	14d	15d	Reference
Dog biscuit	USA, Florida[2]	June 72	?	273	58											Winkler et al. 1975
Ground meat	SWI, Bern[2]	Sept 72	?	210	49	71	82	90	98	99	100					Wandeler et al. 1975
	SWI, Bern[2,3]	Winter 72/73	?	120	38	70	81	88	97	98		99	100			
Chicken head	SWI, Bern[2,3]	Winter 72/73	?	120	33	72	81	87	95	97	98	99	100			Wandeler et al. 1975
	GER[2]	73–74	16–20	[4]5,327			43–78		58–92				70–95			Manz 1976
	SWI, Valais	Oct 78	12.1	150		63										Steck et al. 1982
		Oct 81	14.7	103	18	53										Capt and Kappeler, unpubl.
		Oct 82	16.5	107	17	41										
	SWI, Bern	Sept 83	14.7	260	23	38										Capt and Kappeler, unpubl.
	SWI, Bern[2,5]	May–Jun 88	15	147		61		79					95			Antognoli 1988
	SWI, Bern[2,6]	Sept–Oct 90	13.3	220		38		55					76			Kappeler 1990
	GER, Bavaria	Autumn 83	15.6	492										80		Schneider 1984 unpubl.
	GER, Baden	Autumn 83	16.7	524										84		
	GER, Hesse	Spring 83–85	15	3×360			39				61			81		Wachendörfer et al. 1986
		Oct 83–84	15	2×360			28				62			85		
	ITA, Brescia	Nov 84	10.7	551			26				42			61		Balbo and Rossi 1988
		May 85	10.7	537			32				68			85		
	BEL	Oct 87	40–50	250			21				42				70	Pastoret et al. 1988
Tübingen	GER	85–88?	15	?				30			60			80		Schneider 1989 unpubl.
	ITA	May–Jul 86	11	1,095			21				41			60		Balbo and Rossi 1988
		Mar–Apr 87	13	1,041			18				35			51		
	BEL	Sep 86	11	185			29				47			65		Brochier et al. 1988
		Jun 87	11	312			30				50			57		
		Sept 87	11	292			42				61			72		
	LUX	Sept 86	15	639			28				43			58		Frisch et al. 1988
		May 87	15	754			21				45			64		
		Sept 87	15	584			30				52			66		
	CZE	Spring 89–91	15–16	34,627										65		Matouch 1994 unpubl.
		Autumn 89–91	15–16	34,538										74		
	FIN	Sept 88	15	240			12				31			51		Nyberg et al. 1992
SFE–tallow[7]	SWI, Aargau	Apr 87	11.6	295		6		5d: 27					11d: 51			Antognoli 1988
Wusterhausen[8]	GER[2]	Apr 89	?	280			35		73			86			92	Stöhr et al. 1990b
	GER	Oct 89	16	500+			37			72				82		Stöhr et al. 1990a
	GER	89–90	16–20	10,367			35			61				75		Müller et al. 1993a
	GER, Brandenburg[2]	Apr 91	?	100			18			39				48		Müller et al. 1993a
Raboral V–RG	BEL	Oct 88	15	238			27				54				69	Brochier et al. 1990b
	FRA, V.d'Oise	May 92	20	220						63				83		Ruette 1993
	FRA, Essone	Jun 92	18	95		42				74				84		
Virbac	SWI, Bern[2,6]	Sept–Oct 90	13.3	220		38		55					76			Kappeler 1990 unpubl.
Rabifox Oral	SWI, Solothurn	Apr 91	15	148	43	67		88					97			Matter et al. 1991 unpubl.
Rabifox "Dessau"/ Altrofox 91	GER, Brandenburg[2]	Apr 91	?	400			43		75					93		Müller et al. 1993a

Lysvulpen	CZE	Spring 93	15–16	38,412					82	Matouch 1994 unpubl.
	CZE	Autumn 93	15–16	43,780					82	
Blister pack	ONT, Huron[2,9]	87	800	405			25–87			Bachmann et al. 1990

[1] USA = United States of America, SWI = Switzerland, GER = Federal Republic of Germany, ITA = Italy, BEL = Belgium, LUX = Luxembourg, CZE = Czech Republic, FIN = Finland, FRA = France, ONT = Province of Ontario, Canada.

[2] Tests done without vaccine.

[3] Comparative tests with chicken heads and baits made from ground meat.

[4] Baits were put out in groups of 5 at 814 bait stations in a total of 13 trials.

[5] Two comparative tests with chicken heads and other bait types (sausage, tallow/fishmeal bait) distributed in same area but not at same bait stations.

[6] Three comparative tests with chicken heads and Virbac Rabifox Oral baits distributed in same area but not at same bait stations.

[7] Bait based on 41 percent beef tallow, 41 percent paraffin, 12 percent Witepsol (wax), 5.2 percent water, 0.5 percent synthetic fermented egg attractant (Bullard et al. 1978). Approximately 5,500 baits were distributed in one campaign in Switzerland as part of a project of the Swiss Rabies Center aimed at replacing chicken heads with a bait that allowed for semiautomated production.

[8] Precursor of Rabifox "Dessau" / Altrofox 91; see table 2.

[9] Baits without and with different types of perforated and unperforated plastic bags placed in parallel rows with 35 m between baits and rows on small plots. Bait disturbance, defined as biting, chewing, or moving the cube, was signficantly higher for baits without bag (87 percent *v.* 25–78 percent).

World Health Organization Collaborating Centre in Tübingen investigated other bait types as an alternative to the labor intense preparation of chicken-head baits. This effort led to the development of a bait based on vegetable fat and fishmeal suitable for semiautomated production and containing a blister pack similar to that used for the chicken-head bait.

Following placebo bait trials in the fall of 1985 in Bavaria, the so-called Tübingen fox bait was exclusively adopted for use not only in Germany but also in many other European countries for several years (Schneider et al. 1988, Wilhelm and Schneider 1990).

A new bait, originally developed for raccoons (Hanlon et al. 1989), was introduced in 1988 along with a vaccinia:rabies recombinant vaccine, Raboral V–RG®. It consisted of fish oil and fishmeal bound by a synthetic polymer, ethylene vinyl acetate (EVA), known as Aquabind® (E. I. DuPont de Nemours). The vaccine, sealed in a plastic pouch, was held within the bait by a wax mixture (table 2, fig. 1). First used in Belgium in the autumn of 1988, it was found to be efficient both in captive and free-ranging foxes (Brochier et al. 1990a and b).

All other commercial baits introduced in Europe between 1989 and 1992 have resembled the Tübingen bait and been based on animal or vegetable fat and fishmeal, or meat and bonemeal, containing a blister pack as a vaccine container (table 2). The blister pack bait developed in Ontario in 1987 is similar to the above design but contains chicken "essence" rather than fish as flavor (Bachmann et al. 1990).

Although all of the above baits have been tested in captive animals and in pilot field trials, a questionnaire survey of all manufacturers revealed that very little information is available from these tests, especially those that were conducted to develop a certain bait matrix (table 3). Of special note is an evaluation carried out by the French wherein all three bait types used in France (Tübingen, Virbac Rabifox Oral®, Raboral V–RG) were compared in captive foxes. Each of 36 foxes received a single bait, and all but 1 consumed it. Independent of the bait type, only half of the foxes were protected from a virulent challenge given 34 days after bait consumption (Artois et al. 1993).

These findings may underline both the importance of sufficiently high bait densities in field trials to increase the chances of multiple uptakes by the same individual, and baits that deliver a high-titered vaccine efficiently to the target organ. Video surveillance of the behavior of captive foxes confronted with the Virbac Rabifox Oral or Raboral V–RG baits revealed that baits, though rarely rejected, were often bitten to pieces that were then consumed one after the other. Such feeding behavior may so significantly restrict exposure to the vaccine as to reduce its efficacy (Ruette 1993). In this regard, properly prepared chicken-head baits may have been advantageous over the early variants of the artificial baits in that thorough chewing is required before the blister pack or its remains can be separated from the bait.

Field Evaluation of Baits

The fate of baits during field tests has been monitored in two ways: by checking individually marked baits for disappearance (table 1), and by searching for the tetracycline biomarker in target and, less frequently, nontarget animals collected in the vaccination zone (table 4). While disappearance rates may give some information on the overall attractivity of a bait, it is usually hard to assess the percentage of baits that is taken by foxes. Identification of tooth imprints in empty blister packs found at baiting sites (Antognoli 1988, Matter et al. 1991 unpubl.), fecal markers incorporated into baits (Wandeler et al. 1975), and small radio-transmitters implanted in baits (Rosatte et al. 1991) have been used with some success.

In a comparative trial in Germany, the identification of tracks found at the (unprepared) site of bait placement allowed Müller et al. (1993a) to identify wild hogs *(Sus scrofa)* as important competitors that took 6–15 percent of all baits, while foxes accounted for 13–24 percent of Altrofox and 34 percent of Wusterhausen baits that were removed. Using tracks, Matter et al. (1991 unpubl.) were able to identify the species for 25 percent of Virbac Rabifox Oral baits taken: 14 percent had been removed by foxes, 9 percent by cats and dogs, and 2 percent by other species.

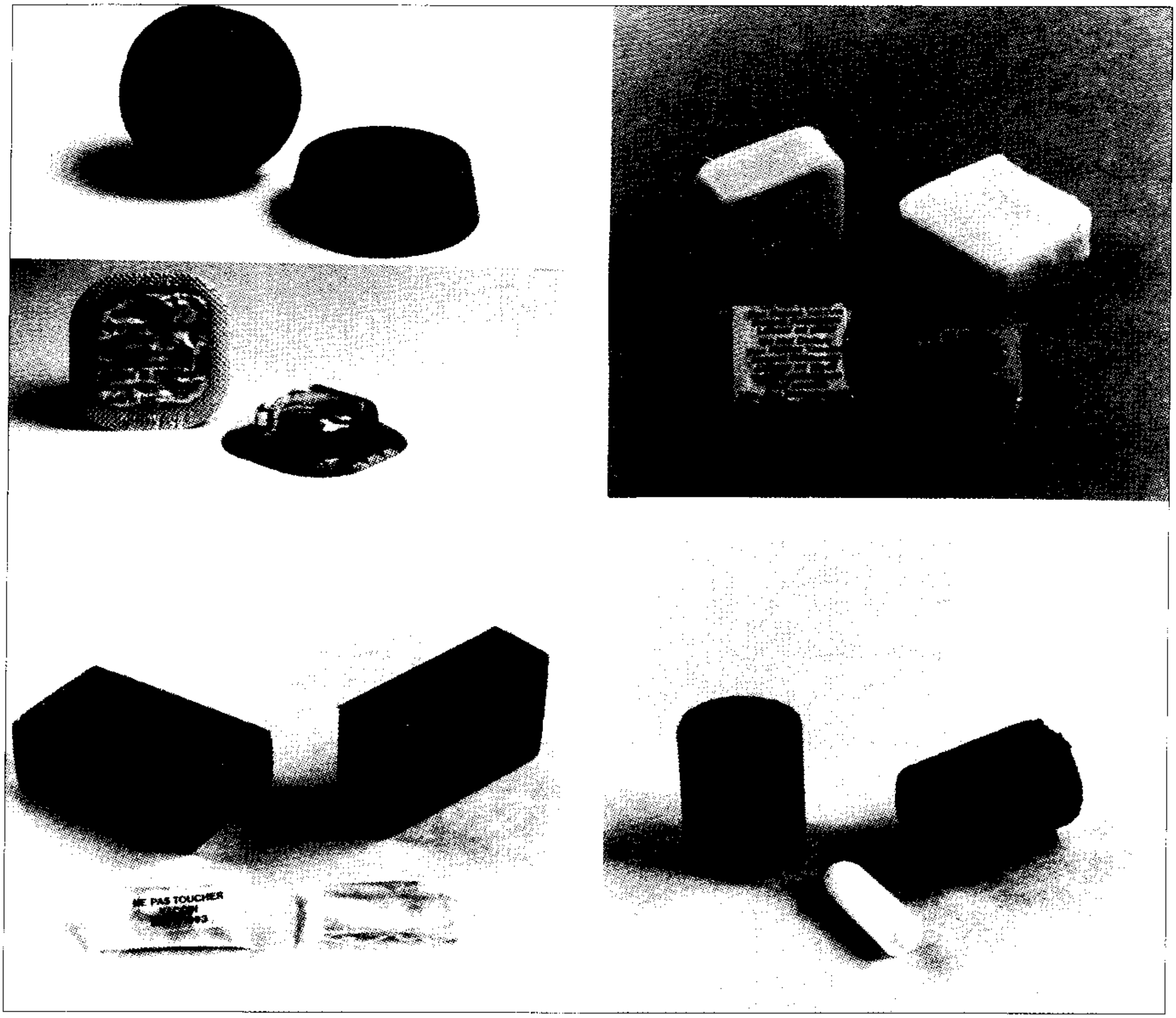

Figure 1. Examples of molded and extruded baits and vaccine containers used in oral vaccination campaigns of foxes and raccoons. Upper left: Rabifox 'Dessau' bait (41 × 15 mm); upper right: Ontario blister-pack bait (35 × 35 × 20 mm); lower left: Raboral V–RG bait as used for foxes in Europe (50 × 30 × 20 mm), lower right: cylindrical Raboral V–RG bait used for raccoons (28 × 35 mm).

In the Czech Republic, several thousand baits were checked in each campaign by the same hunters who had distributed them. Between 46 and 60 percent of the Tübingen baits and 68–71 percent of the Lysvulpen® baits that had disappeared were considered to have been taken by foxes (Matouch 1994 unpubl.). This is in sharp contrast to a French study, where 783 baits of three different types (Tübingen, Virbac Rabifox Oral, Raboral V–RG) were monitored with photo traps for 7 days. Foxes appeared on only 3 of 81 photos that were suitable for evaluation, 1 for each bait type (Ruette 1993). Other visiting species included mainly raptors, corvids, and cats for chicken heads, and hedgehogs *(Erinaceus europaeus)* for both artificial baits, which also received considerable attention from cattle.

Table 2. Characteristics of commercially produced baits used for the oral vaccination of foxes against rabies in Europe and Canada. Information was collected from manufacturers[1] by questionnaire survey in spring 1994[2].

	Chicken head[1]	Tübingen bait (Fuchsoral®)	Rabifox 'Dessau'/ Altrofox 91 bait	Raboral V–RG	Virbac Rabifox Oral
Shape	Chicken head	Rectangular tablet	Round tablet	Cube	Rectangular tablet
Dimensions (mm)	—	42 × 42 × 15	41 × 15	50 × 30 × 20	45 × 50 × 13
Weight (g)	30–80	17–20	14–17	35	27
Color	Meat	Dark brown	Dark brown	Brown	Dark brown
Bait matrix	Chicken head	Fishmeal coconut fat wax	Meat/bonemeal fish animal fat	Plant and animal protein, fish oil, aggregated by synthetic polymer	Fishmeal beef tallow
Manufacturing process	(Slaughter-house)	Molded, semiautomated	Molded, semiautomated	Extruded, automated	Molded, automated
Enhancers and additives	None	None	Animal fat	None	Fish flavor
Melting point of matrix	N/A	Approx. 42 °C	48–55 °C	250 °C	> 50 °C
Biomarker[3]	150 mg TC	150 mg TC	150 mg TC	150 mg TC	150 mg TC
Vaccine strain[4]	SAD_{BERN} SAD B19 (GER, ITA)	SAD B19	SAD P5/88	VVTGgRAB = V–RG (Vaccinia rec.)	SAG–1 SAG–2
Typical titre ($TCID_{50}$/dose)[5]	$10^{7.3}$	10^7, min. 10^6	10^7, min. $10^{6.2}$	$>10^{6.5}$	$>10^8$
Vaccine container, material[6]	Blister, A/PVC	Blister, A/PVC	Blister, A/PP	Pouch, P	Blister, A/PVC
Volume of vaccine (mL)	1.8	1.5	1.8	2.5	1.8
Storage requirements for bait	4 °C	–20 °C	–20 °C	4 °C or ambient	–20 °C
Shelf life	2–4 days	1(–2) years	2 years	18 months	6–12 months
Warning labels on bait on vaccine container	 No Yes	 No Yes	 No Yes	 Yes Yes	 No Yes
First field release with vaccine Country[7], number of baits	Autumn 1978 SWI, 5,800	Autumn 1985 GER, 180,000	Autumn 1989/91 GER, 45,000	Autumn 1988 BEL, 6,000	Autumn 1990 FRA, 201,000
Countries using bait[7], years, method of bait distribution[8], number of baits used[9,10]	SWI, 1978–90 MH 1,300,000 GER, 1983–85 M 476,000 ITA, 1984–85 M 15,000 FRA, 1987 M 3,200	GER, 1985–MF AUS, 1986–M BEL, 1986–92 MH FRA, 1986–92 MH ITA, 1986– M LUX, 1986–91 MH FIN, 1988– MF NET, 1988–? M SVN, 1988–M CZE, 1989–92 M HUN, 1992–F POL, 1993–F	GER, 1989–MF 12,000,000 (improved bait since 1991)[1]	BEL, 1988–FH 1,000,000 FRA, 1989–H 3,000,000 + LUX, 1992–FH 300,000	FRA, 1990–H 3,000,000 SWI, 1991–M 455,000
Total up to 1993	1,794,200	[10]34,646,000	12,000,000	4,300,000 +	3,455,000

	Lysvulpen[1]	Kamark	Meatball bait[11,12]	Sponge bait[12]	Ontario blister-pack bait
Shape	Half-oval tablet	Round tablet	Meatball	Cube	Cube
Dimensions (mm)	50 × 35 × 17	40 × 20	?	40 × 40 × 30	35 × 35 × 20
Weight (g)	18–20	36 ± 6	30	41 (+ attractant)	17–20
Color	Brown/grey	Brown/grey	Meat	Caramel	Pale yellow to beige
Bait matrix	Beef tallow Fishmeal	Beef tallow Fishmeal Dried milk	Ground meat, placed in polyethylene bag	Polyurethane sponge coated with mixure of paraffin, tallow, microbond wax	59% tallow 32% microbond wax 8% mineral oil 1% chicken flavor essence
Manufacturing process	Molded, semiautomated	Molded, semiautomated	Manual	Sponge dipped in mixture	Molded, automated
Enhancers and additives	Yes	None	?	Beef liver slurry or ground beef, added to cube in plastic bag	Platic bag in some early trials[1]
Melting point of matrix	40 °C	45 °C	N/A	?	60 °C
Biomarker[3]	150 mg TC	100 mg CTC	TC	75–140 mg TC	100–150 mg TC
Vaccine strain[4]	SAD_{BERN}	Vnukovo–32/107	No vaccine	$ERA–BHK_{21}$	$ERA–BHK_{21}$
Typical titre ($TCID_{50}$/dose)[5]	10^7	$>10^{5.6}$ $MICLD_{50}$[5]	N/A	?	$10^{7.0}–10^{7.5}$ $TCID_{50}$
Vaccine container, material[6]	Blister, A/PVC	Blister, PS	N/A	PUS	Blister, PVC/PF
Volume of vaccine (mL)	1.8	2.0	N/A	14.0	1.8–2.0
Storage requirements for bait	–20 °C	–18 °C	?	–20 °C	–30 °C
Shelf life	120 days	?	?	?	> 1 year
Warning labels on bait on vaccine container	 No Yes	 No Yes	 ? N/A	 On plastic bag No	 Yes Yes
First field release with vaccine country[7], number of baits	Spring 1992 CZE, 245,000	Spring 1992 SVK, 30,000	? ONT, ?	Autumn 1985 ONT, 10,700	Autumn 1987 ONT, 27,700
Countries using bait[7], years, method of bait distribution[8], number of baits used[9]	CZE, 1992–M 2,426,000	SVK, 1992–M 230,000	ONT, 1976–? F 150,000 ?	ONT, 1985–86 F 25,700	ONT, 1987–F 3,100,000
Total up to 1993	2,426,000	230,000	150,000 ?	[13]25,700	[13]3,100,000

[1] Manufacturers of baits and vaccines:

Chicken head baits were produced locally by veterinary and wildlife services. SAD_{Bern} was produced by the Swiss Rabies Centre, University of Bern, Laenggass-Str. 122, 3012 Bern, Switzerland. SAD B19 was produced by the WHO Collaborating Centre in Tübingen (see below).

Tübingen bait, marketed as 'Fuchsoral' since 1992, was manufactured by Klocke Pharma-Service GmbH, PSF 1140, Rudolf-Diesel-Str., 73356 Weingarten, Germany. SAD B19—originally produced by WHO Collaborating Centre for Rabies Surveillance and Research, Federal Research Centre for Virus Diseases of Animals, P.O.Box 1149, 72001 Tübingen, Germany—is currently produced by Impfstoffwerk Dessau–Tornau (see below).

Rabifox 'Dessau'/Altrofox 91 bait (introduced in 1991) was developed in a collaborative effort by Impfstoffwerk Dessau–Tournau GmbH, PSF 214, 06855 Rosslau, Germany, and Altromin/Sana–Service GmbH, Knobelsdorffallee 26, 06847 Dessau–Mosigkau, Germany. It is produced by Impfstoffwerk Dessau–Tornau. In 1989, the vaccine had been used in 45,000 "Wusterhausen" baits, which were based on fish oil, fishmeal, fat, paraffin, and propylene glycol (Müller 1993a).

Raboral V-RG is produced by Rhône–Mérieux SA, 29, Avenue Tony Garnier, BP 7123, 69348 Lyon Cedex 07, France.

Virbac Rabifox oral is produced by Laboratoires Virbac, BP 27, 06511 Carros Cedex, France.

Lysvulpen is produced by Bioveta, Komenského 212, 68323 Ivanovice na Hané, Czech Republic.

Kamark is produced by Mevak a.s., Biovetská 32 p.s.29/c, 94991 Nitra, Slovak Republic.

Meatball bait was produced by the Ontario Ministry of Natural Resources (OMNR), Wildlife Research, P.O. Box 5000, Maple, ON L6A 1S9, Canada.

Sponge bait: The bait was produced by OMNR (see above); the vaccine was produced by Connaught Laboratories Ltd, 1775 Steeles Ave. West, Willowdale, ON M2R 3T4, Canada.

Ontario blister-pack bait: The vaccine and the bait were originally produced by Connaught (see above). Since 1992, both vaccine and bait have been produced by Langford, Inc., 400 Mitchener Road, Guelph, ON N1K 1E4, Canada.

[2] Additional bait types are or were used in Belarus (fish, chicken heads, injected with Bye1NIIEV-VGNKI strain; Kovalev et al. 1992), in Lithuania since 1992 (pieces of fish, injected with EVHTI-VVMK71, a derivative of the Vnukovo strain; Petkevicius 1993), in Latvia since 1993 (Vnukovo strain, bait?), and in Russia (SIP-RB-71, derived from Pasteur strain, in chicken heads) (Matouch pers. comm.).

[3] CTC = chlorotetracyline, TC = tetracycline (hydrochloride salts).

[4] References for vaccine strains: SAD_{Bern}: Häfliger et al. (1982), SAD B19: Schneider and Cox (1983), SAD P5/88: Sinnecker et al. (1990), SAG-1: Leblois et al. (1990), SAG-2: Lafay et al. (1994), VVTgRAB: Kieny et al. (1984), ERA: Lawson et al. (1987, 1992).

[5] $TCID_{50}$ = 50-percent Tissue Culture Infective Dose; $MICLD_{50}$ = 50 percent Mouse Intracerebral Lethal Dose.

[6] Material used for blisters: A/PP = aluminum and polypropylene, A/PVC = aluminum and polyvinyl chloride, P = plastic sheet, PS = polystyrene, and PUS = polyurethane sponge, and PVC/PF = PVC and paper foil.

[7] Country abbreviations: AUS = Austria, BEL = Belgium, CZE = Czech Republic, GER = Federal Republic of Germany, HUN = Hungary, ITA = Italy, LUX = Luxembourg, NET = Netherlands, ONT = Province of Ontario, Canada, POL = Poland, SVK = Slovak Republic, SVN = Slovenia, SWI = Switzerland.

[8] F = by fixed-wing aircraft, H = by helicopter, M = manually by ground crew (usually with car).

[9] Total number of baits used, based on data provided by manufacturers. Estimates, indicating the minimum number used, are marked "+."

[10] The number of Tübingen baits used in individual countries: GER 20,946,000, AUS 4,100,000+, BEL 450,000, FRA 1,600,000, ITA 160,000+, LUX 450,000+, FIN 320,000+, NET 5,000+ ?, SVN 360,000+, CZE 1,435,000, HUN 320,000, POL 1,400,000. In addition, Tübingen baits with and without vaccine and with the anthelmintic Praziquantel were used in six field trials aimed at controlling *Echinococcus multilocularis* in fox populations in Bavaria, Germany, between 1989 and 1991 (Schelling et al. 1991).

[11] Meatball bait was never used with vaccine but was extensively tested in the field (Johnston and Voigt 1982).

[12] According to Bachmann et al. (1990) and Johnston and Voigt (1982). (No information was received through questionnaire.)

[13] Additional baits without vaccine were distributed in baiting trials in 1984 (sponge bait) and from 1987 onward with blister-pack bait (Bachmann et al. 1990).

Table 3. Evaluation of baits used for the oral vaccination of foxes against rabies in Europe and Canada. Information collected from manufacturers[1] by questionnaire survey in spring 1994.

	Chicken head[1]	Tübingen bait (Fuchsoral)	Rabifox 'Dessau'/ Altrofox 91 bait	Raboral V–RG	Virbac Rabifox Oral
Evaluation of baits: captive animals					
Captive animals in which baits were tested to determine attractivity (placebo or vaccine baits)	red fox	red fox	red fox dog wild boar	red fox dog	red fox
Test type: preference (A) or acceptance (B)	B	A, B	A, B	A, B	A, B
Bait matrix changed due to test	No	Yes	Yes	No	No
Vaccine container changed due to test	No	No	No	No	No
Captive animals in which final product was tested	Red fox	Red fox	Red fox dog	Red fox	Red fox dog
Responses measured[2]	VNA, CR, TC	VNA, CR, TC	VNA, CR, TC	VNA, CR, TC	VNA, CR
Evaluation of baits: field tests					
Pilot studies in field done prior to release of final product	Yes	Yes	Yes	Yes	Yes
Method of bait distribution	Ground	Ground, aerial	Ground, aerial	Ground	Ground, aerial
Responses measured[3]	DR,SI	DR,TC-T,TC-NT	DR,SI,TC-T	DR,SI,TC-T,TC-NT	DR,SI,TC-T,TC-NT
Bait or vaccine container modified due to tests	No	No	Yes, melting temp. of matrix	No	No
Suitability and conditions for aerial distribution tested	Yes	Yes	Yes	Yes	Yes
Altitude	<= 100 m	<= 100 m	<= 100 m	300 m	60–100 m
Groundspeed (km/h)	80–120	120–180	120–180	300	180–200
Losses, surface	< 10 %, prairie < 30 %, gravel	< 1 %, prairie	< 1 %, ?	0 %, tarmac	4 % (*n*=50), pavement
Bait or vaccine container modified after release of final product into the field	Yes, shape and size of blister	Yes, shape of blister	Yes, matrix and shape of bait	Yes	Yes, melting temp. of bait matrix
Reason for modification	Improve bait, manufacturing	Manufacturing process	Manufacturing process	Improve bait, manufacturing	Improve bait, manufacturing

Table 3—Continued

	Lysvulpen	Kamark	Meatball bait[4]	Sponge bait[5]	Ontario blister-pack bait
Evaluation of baits: captive animals					
Captive animals in which baits were tested to determine attractivity (placebo or vaccine baits)	Red fox	None	Yes	?	Red fox striped skunk raccoon
Test type: preference (A) or acceptance (B)	B	—	?	?	A; additional tests with same bait, different attractants
Bait matrix changed due to test	No	—	?	?	Yes
Vaccine container changed due to test	No	—	—	?	No
Captive animals in which final product was tested	Red fox	Red fox	—	Red fox striped skunk raccoon	Red fox
Responses measured[2]	VNA, CR, TC	TC	—	VNA	VNA, TC
Evaluation of baits: field tests					
Pilot studies in field done prior to release of final product	No	Yes	Yes	Yes	Yes
Method of bait distribution	—	Ground	Aerial	Aerial and ground	Aerial and ground
Responses measured[3]	—	DR, TC-T	TC-T	DR, TC-T, TC-NT	DR, TC-T, TC-NT, caching of bait
Bait or vaccine container modified due to tests	—	No	?	?	Yes, smaller bait of 17 instead of 20 g
Suitability and conditions for aerial distribution tested	Preliminary trials indicate suitability	No	Yes	Yes	Yes
Altitude (m)		—	?	100	[5]100
Groundspeed (km/h)		—	?	130	[5]130
Losses, surface		—	?	?	?
Bait or vaccine container modified after release of final product into the field	No	Yes	Bait never used with vaccine	Replaced by blister-pack bait	Yes, different oil (92) lower weight (93)
Reason for modification	—	Manufacturing process	—	Manufacturing process	Improve bait

[1] See table 2, footnote 1 for names of manufacturers.

[2] CR = challenge resistance, TC = biomarker as proof of bait uptake (tetracycline), VNA = virus neutralizing antibodies.

[3] DR = bait disappearence rate; SI = species identification based on tracks, tooth marks in blisters, etc.; TC-NT = biomarker (tetracycline) in nontarget species; TC-T = biomarker in target species.

[4] Meatball bait was never used with vaccine but was extensively tested in the field (Johnston and Voigt 1982).

[5] Information from Lawson et al. (1987) and Bachmann et al. (1990); no information received through questionnaire.

Table 4. Percentage of foxes positive for tetracycline (TC) after manual ground distribution or aerial distribution by helicopter or fixed-wing aircraft of baits containing oral rabies vaccine as well as TC as a biomarker

Bait type	Location[1]	Time	Bait density (no./km²)	Method of bait distribution	Sampling period[2]	Age[3]	*n*	% TC positive (range)	Reference
Chicken head	SWI, mountain valleys	1978–90	13.6	Ground	1–240, summer	Juv	[4]282	36	Kappeler 1991
						Ad	[4]222	64	
					1–240, winter	Subad	[4]1,592	59	
						Ad	[4]1,016	71	
	SWI, plateau and Jura hills		13.1	Ground	1–240, summer	Juv	[4]516	34	Kappeler 1991
						Ad	[4]420	76	
					1–240, winter	Subad	[4]2,024	63	
						Ad	[4]1,252	78	
	GER	1983–85	15	Ground	31–180, all year?	?	[4]2,231	75 (68–90)	Schneider et al. 1988
	ITA	Nov 84	10.7	Ground	30–170, winter	?	[5]46	63	Balbo and Rossi 1988
		May 85	10.7	Ground	30–170, summer	?	[4]21	43	
Tübingen	GER	1985–86	15(–20)	Ground	31–180, all year?	?	[4]1,278	73 (65–81)	Schneider et al. 1988
		Spring 87	15	Ground	?	?	[5]208	90	Schneider and Cox 1988
	ITA	Spring 86	11	Ground	30–170, summer	?	[5]199	42	Balbo and Rossi 1988
		Spring 87	13	Ground	30–170, summer	?	[4]107	36	
	BEL	Sept 89	15	Ground	15–240, winter	?	[4]97	61	Brochier et al. 1991
		June 90	14	Aerial	1–160, summer	Juv	[4]55	49	
						Ad	[4]31	80	
	AUS	1986–91	16	Ground	All year	?	[4]7,053	>70	Kissling and Gram 1992
	LUX	Autumn 86	15	Ground	24–90, winter	?	[5]157	62	Frisch et al. 1988
		Spring 87	15	Ground	22–65, summer	?	[4]114	71 (juv: 56)	
	CZE	Spring 89–91	15–16	Ground	Summer	?	[4]831	74 (56–83)	Matouch 1994 unpubl.
		Autumn 89–91	15–16	Ground	Winter	?	[4]1,106	68 (53–73)	
	FIN	1988–89	15	Ground/aerial	30–210, all year	?	[4]56	88	Nyberg et al. 1992
	FRA[6]	1989–92	13	Aerial	Summer	Juv	[4]26	46	Masson et al. 1993 unpubl.
						Ad	[4]31	90	
					Winter	Subad	[4]26	50	
						Ad	[4]18	67	
Wusterhausen	GER	Autumn 90	?	Ground	Winter	?	[5]949	78	Müller et al. 1993b
		Autumn 90	17.5	Aerial	Winter	?	[5]1,880	78	
		Spring 91	17.9	Aerial	Summer	Ad+Juv	[4]2,723	67	
Raboral V–RG	BEL	Oct 90	14	Aerial	1–200, winter	?	[4]153	76	Coppens et al. 1992
		May 91	15	Aerial	1–150, summer	?	[4]188	61	
		Oct 91	15	Aerial	1–70, winter	?	[4]66	71	
	FRA[6]	1990–92	13	Aerial	Summer	Juv	[4]114	33	Masson et al. 1993 unpubl.
						Ad	[4]83	81	
					Winter	Subad	[4]43	86	
						Ad	[4]53	85	
Virbac Rabifox Oral	FRA[6]	1991–92	13	Aerial	Summer	Juv	[4]28	32	Masson et al. 1993 unpubl.
						Ad	[4]40	75	
					Winter	Subad	[4]64	88	
						Ad	[4]96	94	

Table 4—Continued.

Bait type	Location[1]	Time	Bait density (no./km²)	Method of bait distribution	Sampling period[2]	Age[3]	n	% TC positive (range)	Reference
Rabifox 'Dessau'/ Altrofox 91[7]	GER, Brandenburg	Apr 91	18	Aerial	Summer	?	[5]79	67	Müller et al. 1993a
Lysvulpen	CZE	Autumn 92	15–16	Ground	Winter	?	[4]1,992	84	Matouch 1994 unpubl.
		Spring 93	15–16	Ground	Summer	?	[4]1,266	76	
Meatball[7]	ONT	Oct, Feb	35	Aerial	?	?	210	70	Johnston and Voigt 1982
		Oct 76/77/80	18–48	Aerial	1–28, Autumn	All	?	48–70	MacInnes 1988
Sponge	ONT	Sept 84–86	17–19	Aerial	1–28[8]	All	[5]275	63 (61–64)	Bachmann et al. 1990
Blister pack	ONT	Sept 87	17–25	Aerial	1–28[8]	All	[5]93	59 (50–67)	Bachmann et al. 1990
	ONT, Toronto[9]	Autumn 89–91	[9]50–70	Ground	?	All	[4]72	72	Rosatte et al. 1992
	ONT, Cambridge	Autumn 90	20	Ground	?	All	[5]180	35	Rabies Res. Unit 1991
	ONT	Oct 90	21.6	Aerial	20–, winter	All	[4]675	67	

[1] See table 1, footnote 1 for country abbreviations. AUS = Austria.

[2] Timeframe (days after bait distribution) and season in which animals were collected. Summer refers to sampling after campaigns in spring, winter to sampling after campaigns in autumn. Although not specified in all references, foxes positive for rabies were usually excluded from the samples.

[3] Age of foxes: Ad = adult (>1 year old), Juv = juvenile, Subad = subadult, All = all age classes.

[4] Sample comprises animals from areas that have been baited previously.

[5] Sample from area that has been treated only once.

[6] The French study compared the performance of three different bait types. The data selected for this table show the results from areas vaccinated three times with the same bait type.

[7] Without vaccine.

[8] Evaluation limited to foxes trapped within 28 days of bait drop because resident population was "diluted" by dispersal (small experimental plots).

[9] Baits distributed along creeks and rivers in metropolitan Toronto, 50–70 baits per kilometer of ravine, and at den sites (20 baits/den).

Gürtler and Zimen (1982) used the same method to evaluate chicken heads and found that 30–55 percent of the baits were removed by foxes. Conversely, Aubert (Ruette 1993) calculated that given a bait density of 13/km² and a fox home-range size of 3 km², only 3.5 percent of all baits would need to be consumed by foxes to reach 75 percent of the fox population, as determined by foxes positive for tetracycline.

Aside from the consumption by obvious competitors such as mustelids, wild hogs, dogs, and cats, a significant proportion of baits may be partially consumed by rodents, snails, and carnivorous insects. Kappeler (1990 unpubl.) found that 12–16 percent of chicken heads distributed in early autumn and checked for 10 days had signs of consumption by insects, while 24–38 percent of Virbac Rabifox Oral baits had been partially eaten by rodents and 23–29 percent, by snails. During an observation period of 14 days, about 30 percent of Tübingen baits (Brochier et al. 1988) and 15–67 percent of Raboral V–RG baits exposed in the field for 2 to 21 days were gnawed by rodents (Ruette 1993). However, partial consumption usually does not preclude a later uptake of the bait by carnivores.

For 2–8 days after their distribution, Bachmann et al. (1990) searched the ground for baits air-dropped in plastic bags. Between 42 and 53 percent of sponge baits (search effort of 8 days) and 11–36 percent of blister pack baits (2 days) had been contacted by animals. Crows had removed 63–87 percent and foxes 10–28 percent of contacted sponge baits. Blister-pack baits dropped without bags could not be located on the ground.

In some instances, only the bait matrix is consumed; an intact blister is left behind. In Swiss trials of chicken heads, 2 percent of blister packs were found intact (Capt and Kappeler, unpubl. data). In some early field trials, Schneider (1984 unpubl.) reported that 15–17 percent of the blister packs in chicken-head baits were found intact but attributed the high rate to poor bait quality. Intact blister packs were found for 7.5–16 percent of 639 Tübingen baits in Belgium (Brochier et al. 1988) and for 3.2 percent of Wusterhausen baits tested in Germany (Stöhr et al. 1990a).

The most widely used technique to monitor bait uptake by target and nontarget species has been the detection of tetracycline in thin sections of mandibular bones (most studies), femur (Capt 1981, Kappeler 1991), and calcified teeth (Bachmann et al. 1990). Tooth sections enable investigators to determine multiple bait uptake by juvenile and subadult animals, provided that ingestion occurred on different days. The method may also be used to determine the precise date of bait consumption provided the date of animal death is known (Johnston et al. 1987). While routinely used in Ontario, this technique has received only limited attention in Europe (Capt 1981, Hässig 1984, E. Masson, pers. comm.).

Tetracycline data are best used to compare samples collected and evaluated under identical conditions. However, direct comparisons between bait types and countries as shown in table 4 are difficult because such conditions may differ. Comparisons are further confounded because of missing information as to the time period over which animals were collected, the age composition of the sampled animals, and the number of previous baiting campaigns. Investigators who reported 90 percent tetracycline-positive animals (n = 208) following a single spring campaign (Schneider and Cox 1988) likely restricted their analysis to adult animals only or placed baits selectively at fox dens, or both. Using data from more than 13,000 foxes collected in areas treated with chicken-head baits in Switzerland between 1978 and 1990, Kappeler (1991) showed that repeated baiting campaigns, campaigns conducted in fall, use of high bait densities, and, with respect to juvenile foxes, campaigns carried out late in spring increased the percent of tetracycline-positive foxes. Adult foxes were more likely to have taken bait and so were animals from the Swiss Plateau rather than from less accessible mountain valleys.

Other species shown to compete for bait were stone marten (*Martes foina;* 46 percent marked), badgers (21 percent marked), and other small mustelids and domestic cats. However, the probable influence of these nontarget species on bait uptake by foxes could not be determined (Kappeler 1991). The above observations have been confirmed in part by studies in France (Masson et al. 1993 unpubl.) and in Ontario, where the percentage of foxes positive for tetracycline increased with bait density in trials with 12.5 to 50 baits/km^2 (Rabies Research Unit 1991). Bait uptake by nontarget species was found in several other countries for various bait types as well, primarily in mustelids and wild hogs but also in a low percentage of sampled rodents and cervids (Schneider 1984 unpubl., Kalpers et al. 1987, Paquot et al. 1988, Stöhr et al. 1990b, Coppens et al. 1992, Müller et al. 1993a).

Baiting Strategies

Both temporal and spatial distribution strategies play an important role in maximizing the percentage of target animals that take baits. Foxes usually live in family territories within most of their geographic range and are opportunistic in their feeding behavior. Uniform distribution of baits is therefore more likely to give many individuals access to one or a few baits than would be the case with clusters of baits at bait stations (Hässig 1984), even when some habitat types are given preferential treatment. This concept was reflected from the onset of the bait distribution strategies used in Europe and Canada. The goal of 15 baits/km^2 set for the initial field trials in Switzerland served as a reference density for most European countries (tables 1 and 4). Higher densities of up to 25 baits/km^2 were sometimes used to control residual rabies foci and in areas where the fox population had increased significantly (Frost et al. 1985, U. Breitenmoser, pers. comm.).

Baits can be efficiently distributed by ground crews using vehicles, provided that an adequate road network is present, although bait placement (and camouflage) by hand rather than broadcasting baits from vehicles should be emphasized. In practice, manual distribution is usually carried out by game wardens, forestry personnel, and most often hunters, who distribute baits in their own hunting preserve at no or little cost to the state. The actual sites where baits are to be deposited are either predetermined and shown on a map, prepared by or in collaboration with local hunters, or by grids plotted on a map that serve as guidance. This distribution strategy was first employed in Switzerland (Steck et al. 1982, Kappeler 1991) and later adapted by Germany to meet specific local needs and hence was termed the "Bavarian model" (Schneider 1984 unpubl., Wilhelm and Schneider 1990). With slight modifications, it also served as a model for all the European countries where baits were distributed manually (Rigal 1987, Brochier et al. 1988, Frisch et al. 1988, Stöhr 1990a, Kissling and Gram 1992, Nyberg et al. 1992, Matouch 1994 unpubl.).

Ontario developed a system for the aerial distribution of potential vaccine baits long before embarking on oral vaccination campaigns (Johnston et al. 1988 and this volume); however, aerial bait distribution was uncommon in Europe until the late 1980's. From 1979 through 1984, the Swiss used helicopters in inaccessible mountain areas, but the vast majority of chicken head baits were distributed by ground crews (Kappeler 1991). In 1988, with increasingly larger areas to treat, France began using helicopters and soon completely abandoned ground distribution (Aubert et al. 1993). Residual foci of rabies in wetland areas first prompted the use of fixed-wing aircraft in Germany in 1988 (Schneider 1989 unpubl.). Because they provide the majority of field specimens for postvaccination surveillance, it was considered essential to keep hunters involved in bait distribution; thus aerial distribution was first considered a tool for emergency situations only. However, given the cost-effectiveness of aerial bait placement, both helicopter and fixed-wing aircraft have become increasingly popular in recent years in Germany as well as in other European countries (table 2). Baits are usually dropped from an altitude of 30–100 m at a groundspeed of 110–180 km/h. A helicopter or small aircraft can cover 750–1,000 km^2/d at a bait density of 13–25/km^2 and at 1–3 flight lines per km^2 (Brochier et al. 1991, Aubert et al. 1993, Müller et al. 1993b). Analysis of foxes from areas that were baited either by ground crews or by aircraft revealed no significant differences in the percentage of animals positive for tetracycline or rabies virus-neutralizing antibodies (table 4, Müller et al. 1993b).

Two baiting campaigns per year, usually in spring and fall, appear indispensable for the European rabies situation; some failures have been associated with a single campaign per year (Schneider 1989 unpubl., B. Brochier and R. Frisch, pers. comm.). Experiments were recently carried out in Germany in areas with a high incidence of rabies wherein baits were also dropped in summer to vaccinate young foxes before dispersal. Similarly, Switzerland is experimenting with an additional baiting campaign in early summer, where baits are placed specifically at fox dens (U. Breitenmoser, pers. comm.). Ontario currently carries out a single annual campaign, in the fall, with good success (Rabies Research Unit 1991).

We have not included in this review serologic or epidemiologic data used to evaluate bait efficacy because doing so inevitably involves at least one further component of oral vaccination programs, the vaccine. In the end, all baiting systems will be measured by the extent to which rabies is eliminated from a given area. Many insights can be expected from the French trials, where three different vaccination systems were used in the same country and evaluated by the same team (Masson et al. 1993 unpubl., Aubert et al. 1994). All the systems mentioned above can claim success in reducing or even eliminating rabies from areas of varying size, but many of them were also involved in cases where initial field trials failed to produce the expected result. Aside from baits and baiting systems, many other factors will exert an important influence on the outcome of oral vaccination campaigns. Thus, most likely it will always be difficult to determine which component(s) of oral vaccination determined the success or failure of efforts to control the disease in nature.

Arctic Fox *(Alopex lagopus)*

Population reduction of arctic foxes in Alaska, U.S.A., has been the primary focus of bait use for this species. This fox was introduced onto several islands in the Aleutian chain in about 1836, where it has been a serious threat to the indigenous avifauna (Bailey 1993). Between 1956 and 1986, poison baits were distributed on various islands to supplement other efforts directed at eliminating this unwanted predator. Bait types used included strychnine pellets imbedded in seal blubber, baits consisting of tallow, seal oil, beeswax, and the toxicant Compound 1080 (sodium monofluroacetate), as well as chicken eggs and fish, seal, and bird carcasses injected with Compound 1080. About 49,000 molded cone-shaped baits made of 90 percent beef tallow and 10 percent beeswax, each weighing 4.3 g and containing 4 mg of Compound 1080, were dropped on Kiska Island (324 km^2) in 1986, where a similar attempt at eliminating the arctic fox had failed in 1964. Within 6 days, 186 fox carcasses were recovered and many more animals were assumed to have died. Surveys in 1989 and 1992 revealed no sign of survivors (Bailey 1993).

Only recently has the baiting of arctic foxes received attention in the context of rabies control. Rabies, known in the north circumpolar region for more than a century, has often been reported in both sled dogs and arctic foxes (Crandell 1991). While dogs can usually be restrained for parenteral rabies vaccination, control of the disease in the arctic fox is much harder to achieve, given the enormous range that would have to be covered. However, oral vaccination of arctic foxes might provide at least some relief if applied in restricted areas around remote villages and industrial sites to protect humans from the disease. It was with this premise in mind that Follmann et al. (1988, 1992) successfully orally immunized captive arctic foxes against rabies. Six foxes were each given a 10-cm-long sausage bait inside of which was a sealed plastic straw with 1.4 mL of liquid SAD live attenuated rabies vaccine. All foxes accepted and consumed the bait within 1 hour. The size of the bait prevented foxes from swallowing it without thorough mastication and thus perforating the vaccine container. No other baits were tested; but according to E. H. Follmann (pers. comm.), arctic foxes will eat a variety of bait materials.

Rabies moved southward along the coast of Labrador and to the north of Newfoundland, Canada, in 1988. In response to this outbreak, 8,100 Ontario blister-pack baits (see red fox account) containing live attenuated ERA rabies vaccine were distributed by helicopter (Johnston and Fong 1992). Both tetracycline and neutralizing antibodies against rabies were demonstrated in three arctic foxes recovered from one of the treated islands, proving uptake of baits by the target species (World Health Organization 1990b). However, before large-scale vaccination campaigns could be undertaken, a number of obstacles would have to be overcome, for example, the fact that freezing temperatures limit the time of year when a liquid vaccine can be used.

Jackals *(Canis adustus, Canis aureus, and Canis mesomelas)*

Livestock depredations have been the principal reason for using toxic baits to reduce jackal numbers. Technical literature describing specific baits and their application is sparse; however, Hey (1964) reported that, prior to World War II, glass capsules of "prussic acid" were placed in recently killed animals or in the wool about the neck region of live sheep. He also mentioned that strychnine was applied to the gut and intestines of freshly killed ungulates and stirred into the partly digested food and dung to kill black-backed jackals in South Africa. More recently, the humaneness and specificity of strychnine baits for jackal control have been questioned (Allan 1989, Brown 1988), and the use and abuse of strychnine in South Africa was the subject of a colloquium in 1986 (South African Veterinary Association 1986). Allan (1989) stated that 34–60 percent of livestock farmers regularly used poison baits to control mammalian predators. Brown (1988) believed that the widespread placement of poison baits and the poisoning of carcasses on farmlands were responsible for the decline of scavenging birds throughout southern Africa. However, the use of toxicants is more closely regulated at the present time. The effect of strychnine poisoning on wildlife in South Africa also has been discussed in some detail by Dobbs and Benson (1986).

Specific bait types and baiting techniques used in South Africa have been described. In the northern Transvaal, toxicants were delivered in 100-g meat cubes of beef, goat, or warthog *(Phacochoerus aethiopicus)*, or in parts of their intestine. Such baits were placed around the carcasses of livestock which served as draw stations. A study of strychnine bait selectivity and efficacy for black-backed jackals was conducted in July 1985 and 1986 in the northern Transvaal wherein toxic meat pellets and coyote getters were placed every 100 m along 2- to 5-km transects. It was concluded that toxic baits were selective for jackals because civets *(Civettictis civetta)* were not susceptible to the dose levels used in jackal baits. Hazards to nontarget birds were eliminated by burying baits. Toxic baits were normally placed along farm roads and at watering holes at a density of about 10 baits/km. Widespread use and overuse of strychnine baits appeared to have reduced their efficacy (P.J.J. van Rensburg, pers. comm.).

Similarly in Natal, South Africa, sheep or cattle muscle meat and fat have been used to deliver strychnine and Compound 1080. Baits were placed along farm roads, tracks, and along fence rows. Toxicants were occasionally placed in sheep or lamb carcasses; the latter practice resulted in some nontarget species mortality. Legal restrictions in Natal control the type and use of toxicants. Their use is thought to be generally ineffective for reducing livestock losses, except perhaps for control of free-ranging domestic dogs (D. T. Rowe–Rowe, pers. comm.).

Foggin (1990) has briefly summarized the epidemiology of jackal rabies and the use of toxic baits for their control in Zimbabwe. Also in Zimbabwe, experimental baiting tests for black-backed jackals were undertaken in 1990 and 1991 with the objective of developing an oral rabies vaccine delivery system. Rotten offal was used as an olfactory attractant to increase bait discovery and uptake. Up to 70 percent of chicken-head baits were removed by jackals during the first night of bait exposure. Nontarget vertebrates removed about 10 percent of the baits, and bait consumption by beetles and millipedes was a problem in summer if baits were untouched by jackals during the first night of exposure. Captive jackals preferred meat and particularly chicken, but soft baits such as beef meat were swallowed intact.

Chicken heads containing a biomarker (tetracycline) were broadcast over a 250-km^2 area at an average density of 6.5 baits/km of roadway and about 6.3 baits/km^2. Baits were placed beneath vegetation or other cover to minimize their discovery by birds and exposure to direct sunlight. Sampling revealed that 72 percent of the jackals contained evidence of the biomarker. However, it was subsequently found that 37 percent of jackals collected countrywide contained a naturally occurring fluorescence in bones indistinguishable from that induced by tetracycline. Thus, the actual percent of the jackal population on the study area reached by baits was questionable (Bingham et al. 1992, 1993, and 1994; J. Bingham, pers. comm.).

Strychnine baits also have been used in some of the middle eastern countries to destroy jackals and foxes where rabies has been a problem, but documentation in the technical literature available to us is poor. Israeli scientists are currently developing oral rabies vaccine technology and baiting techniques for both golden jackals *(Canis aureus)* and red foxes (A. Shimshony, pers. comm.).

Coyote *(Canis latrans)*

The use of small baits to deliver toxicants for coyote control began after the introduction of strychnine in 1847 (Young and Jackson 1951), and continued in the United States until toxicant use was restricted by executive order (Nixon 1972). Baits were also used for delivery of single-dose toxicants (strychnine and Compound 1080) to reduce coyote depredations and to control rabies in Canada (Ballantyne and O'Donoghue 1954, Stewart 1972, Baril 1982, Dorrance 1992) and Mexico (Cocozza and Malaga Alba 1962, Brown 1983). Research to improve bait delivery to coyotes began with an interest in reproductive inhibition to reduce population densities and thereby livestock depredations. An initial field trial in 1963 to deliver baits containing the synthetic estrogen DES to female coyotes showed promise (Balser 1964). Linhart et al. (1968) explored various bait application procedures in subsequent field tests during 1964–67 but were unable to treat a sufficient segment of populations with the antifertility agent.

The executive order restricting toxicant use stimulated research during 1976–91 to evaluate and develop selective delivery of single-dose baits to coyotes. Those studies were directed toward increasing the proportion of coyotes that ingested baits by manipulating (1) the types of baits and associated odor attractants, (2) the distribution and placement of baits, and (3) the persistence of baits, which was largely related to consumption by nontarget animals.

Baits and Odor Attractants

Coyote preference for different types of small baits was first evaluated with captive animals by Tigner et al. (1981 unpubl.). Their pen tests with two sizes (6 g *v.* 12 g) of rendered beef tallow and lean horsemeat showed no effect for bait size but a 2× preference for tallow over horsemeat, as determined by order of consumption. Subsequent observations indicated that coyotes chewed three types of fat baits more than three meat baits before swallowing (Tigner et al. 1981 unpubl.), a finding that may have implications for delivery of certain contraceptives or vaccines.

Three field tests that compared coyote response, as measured by modifications of the scent-station technique (Linhart and Knowlton 1975), to several fat and meat baits showed a trend in preference for fat baits (table 5), although differences were generally not statistically significant. In a field test at Fort Bliss, TX–NM, U.S.A. (Feb. 1979) (table 5), coyotes consumed a greater percentage of the three fat baits (22 percent) than the five meat baits (14 percent) (G. E. Larson and J. R. Tigner, U.S. Department of the Interior, Denver Wildlife Research Center, unpubl. data). Consumption of baits by coyotes closely reflected visitation rates to bait stations and was relatively high in four studies (table 6). Tallow and lard baits used in field tests usually incorporated 10–25 percent beeswax to raise the melting point and hence increase bait persistence in warm conditions (Linhart et al. 1968, Servheen 1983, Knowlton et al. 1986).

The search for a more selective bait-delivery technique led to development of the Coyote Lure

Operative Device (CLOD), a passive mechanical delivery system based on coyote behavioral response to odors (Marsh et al. 1982). The CLOD is a ground-anchored, sealed plastic vial containing a sweet liquid solution (e.g., syrup and sugar), which can potentially serve as a carrier for vaccines, antifertility agents, toxicants, or physiologic markers (Ebbert and Fagre 1987, Scrivner et al. 1987, Stolzenburg and Howard 1989). Coyotes are attracted to CLOD's by a lure applied directly on top of the vial to elicit a biting response that exposes the liquid solution for ingestion. These three research teams also described and illustrated modifications of the CLOD. However, this device has not advanced beyond limited research use.

Odorous substances are routinely used to lure coyotes to foothold traps and sodium-cyanide ejectors (coyote-getter and M-44) (Young and Jackson 1951, Fagre et al. 1983). To improve efficacy and selectivity of coyote control techniques, several investigators have evaluated various odor attractants (table 7). One objective of these studies was to develop superior coyote attractants that could be formulated with consistent chemical and odor properties (Fagre et al. 1983, Turkowski et al. 1983). The studies resulted in development and field testing of several effective synthetic coyote attractants, such as CFA (synthetic monkey pheromone) (Linhart et al. 1977), SFE (synthetic fermented egg) (Bullard et al. 1978, Turkowski et al. 1983), FAS (fatty acid scent) (Roughton 1982), and TMAD (trimethylammonium decanoate) and WU-lure (TMAD plus sulfides) (Scrivner et al. 1987).

Odor attractants have been used to enhance delivery of small baits to coyotes by coating the baits, incorporation into baits, and placement near baits (Linhart et al. 1968, Tigner et al. 1981 unpubl., Servheen 1983, Guthery et al. 1984). Tigner's team used captive animals to compare acceptance of tallow baits with eight different odor attractants incorporated at concentrations of 1, 3, 5, 7, and 9 percent by volume, and found that the higher concentrations resulted in decreased palatability of baits. The Guthery team's field test suggested that coyotes preferred beef-tallow baits with 1 percent aldehydic, fruity, and scatologic fractions of SFE over unscented tallow (table 5). Most field tests of bait efficacy have used odor attractants placed adjacent to baits to increase their attractiveness to coyotes (tables 6 and 8). However, the relatively low percent of coyotes that ingested baits during many field tests (table 8) was likely related to the animals' failure to detect the baits. The development of more effective odor attractants for use with baits may be the key to enhanced delivery.

A complete review of the research aimed at developing synthetic coyote olfactory attractants is beyond our scope. Comprehensive summaries of the basis and criteria for development of coyote olfactory attractants were provided by Bullard (1982, 1985) and Fagre et al. (1983). Further review of studies that compare coyote attractants may begin with the references in table 7.

Recent field tests of the CLOD have evaluated the effectiveness of specific attractants to stimulate the key biting–licking response required to deliver the fluid solution. Ebbert and Fagre (1987) found that CLOD's scented with CDCL (Carman's Distant Call Lure) and WU-lure had greater visitation by coyotes than CLOD's with SFE and Mast's #6. Two other field tests had relatively low visitation by coyotes with no detectable differences among WU-lure (8 percent), SFE (7 percent), and a fetid lure (6 percent) in New Mexico (Stolzenburg and Howard 1989), and among CDCL (10 percent), FAS (8 percent), and WU-lure (7 percent) in Colorado (Hein 1992). The percentage of CLOD's activated by visiting coyotes was relatively low compared with consumption of baits (table 6) and differed among the three field tests. During Ebbert and Fagre's (1987) study in Texas, the percentage of visiting coyotes that ingested the contents of CLOD's averaged 42 (n = 81), and the rate was similar to the percentage activating M-44's, and also similar among the four attractants tested. Stolzenburg and Howard (1989) reported that 55 percent of visiting coyotes (n = 237) activated CLOD's in New Mexico, but the percent of activation was markedly less for CLOD's scented with SFE (26 percent) than with WU-lure (66 pecent) or a fetid lure (78 percent). In contrast, only three CLOD's were activated during 213 coyote visits in Hein's (1992) study in Colorado, a result the investigator attributed to seasonal effects.

Table 5. Rank of coyote preference for different baits based on consumption rate in field tests using modifications of scent-station technique (Linhart and Knowlton 1975)

	Reference, location (U.S.A.), time		
	G. E. Larson and J. R. Tigner, unpublished data Fort Bliss, TX–NM	Guthery et al. 1984 King and Knox counties, TX Oct–Apr 1980–82	Servheen 1983 Goliad and Refugio counties, TX May–June 1981
Beef abdominal fat	2		
Beef tallow (unscented)	1	5	[2]2
Beef tallow (aldehydic odor)[1]		2	
Beef tallow (fruity odor)[1]		1	
Beef tallow (scatologic odor)[1]		3	
Beef tallow (fishy odor)[1]		6	
Beef tallow (mink[3] musk odor)[1]		7	
Lard	3		[2]1
Lean beef meat	4		
Hamburger meat (30% fat)	6		
Horsemeat	5	9	[2]3
Sheep meat	8	4	
Jackrabbit (*Lepus* sp.) meat	7		
Angora goat meat		8	

[1] Odor fractions of SFE (synthetic fermented egg) were incorporated into tallow at 1 percent by volume.

[2] All baits were rolled in fishmeal.

[3] *Mustela vison.*

Table 6. Field tests of bait placement methods using modifications of scent-station technique (Linhart and Knowlton 1975)

Location (U.S.A.) and time	Type of attractant[1]	Bait placement method[2]	% baits visited by coyotes *(n)*	% baits consumed/ coyote-visit	Reference
Fort Bliss, TX–NM Feb 1980	None	Surface	26 (178)	83	G. E. Larson and J. R. Tigner, unpubl. data
	None	Elevated (30–40 cm)	11 (178)	58	
	SFE	Surface	30 (177)	87	
	SFE	Elevated (30–40 cm)	18 (176)	58	
	SFE	Buried (1–2 cm)	23 (177)	63	
Sevilleta National Wildlife Refuge, NM Jan–Feb 1981	None	Surface	17 (203)	94	G. E. Larson and J. R. Tigner, unpubl. data
	None	Elevated (30–40 cm)	10 (202)	84	
	SFE	Surface	21 (201)	93	
	SFE	Elevated (30–40 cm)	13 (200)	84	
	SFE	Buried (1–2 cm)	11 (201)	64	
Fergus Co., MT Sept–Nov 1981	SFE	Surface	8 (591)	94	Baril (1982)
	SFE	Elevated (45.7 cm)	5 (562)	90	
	SFE	Buried (1–2 cm)	6 (554)	84	
Goliad and Refugio counties, TX July 1981	CDCL	Surface	44 (233)	70	Servheen (1983)
	CDCL	Elevated (50.8 cm)	43 (225)	70	
	CDCL	Buried (5–7.5 cm)	37 (238)	43	
	CDCL	Covered[3]	46 (228)	70	

[1] Placed adjacent to bait to attract coyotes; SFE = synthetic fermented egg; CDCL = Carman's Distant Call Lure.

[2] Beef tallow (9.5 g) used a bait in all tests, except for lard (28.3 g) by Servheen (1983).

[3] Bait placed on surface and covered with indigenous materials.

Table 7. Some representative studies of the efficacy of odor attractants for coyotes

Location (U.S.A.) and time	Method of study	Types of attractants tested	No. of attractants compared	Attractants with greatest preference during study	Reference
4 Western States No date	Scent-station procedures	Synthetic, fetid, commercial	≥58	SFE, various others	Turkowski et al. 1979 Turkowski et al. 1983
Hopland, CA 1972–81	Observations of captives	Synthetic, urine	≥30	W-U lure, TMAD	Fagre et al. 1983 Scrivner et al. 1987
Colorado 1982–85	Capture devices	Synthetic, fetid, commercial, urine	45	W-U lure, sheep liver extract, CDCL	Graves and Boddicker 1987
Southern Texas 1982–86	Capture devices	Synthetic, fetid, commercial, urine	3	CDCL	Windberg and Knowlton 1990
Southern Texas 1984	Scent-station procedures	Synthetic, commercial	4	W-U lure, CDCL	Martin and Fagre 1988
Millville, UT 1988–90	Observations of captives	Synthetic	35	W-U lure, FAS	Phillips et al. 1990

Table 8. Field tests of the efficacy of delivery of nontoxic baits to coyotes during winter

Location (U.S.A.) and time	Size of area (km^2)	Initial bait density[1] (no./km^2)	Bait type and size (g)	Type of odor attractant used with bait (method)	Bait distribution method[2] (placement)	No. days of bait exposure (no. of bait applications)	% coyotes with physiologic marker (*n*)	Reference
Deming, NM Feb–Mar 1966	1,700	6.2	95% Beef tallow (9.5) and liver meal	Seal oil (incorporated)	Selective (surface)	28 (4)	28 [4](95)	Linhart et al. 1968
Arivaca, AZ Feb–Mar 1967	1,600	6.1	85% Beef tallow (9.5) and liver meal	Seal oil[3] (incorporated)	Selective (surface/elevated)	28 (4)	34 (119)	Linhart et al. 1968
Rawlins, WY Winter 1976–77	350		Lard (9.5) and fishmeal	None	24 Draw-stations (surface/elevated)	14 (2)	9 [4](55)	Tigner et al. 1981 unpubl.
Fort Sumner, NM Winter 1976–77	350		Lard (9.5) and fishmeal	None	19 Draw-stations (surface/covered)	14 (2)	27 [4](11)	Tigner et al. 1981 unpubl.
Monticello, UT Winter 1978	350		Lard (9.5) and fishmeal	SFE (adjacent)	19 Draw-stations (surface/elevated)	21 (2)	15 [4](26)	G. E. Larson and J. R. Tigner, unpubl. data
Goliad and Refugio counties, TX Jan–Feb 1982	174	0.5	80% Lard (28.3) and fishmeal	CDCL (adjacent)	Systematic (elevated)	30 (3)	18 [4](11)	Servheen 1983
Webb Co., TX (2 areas) March 1985	52	1.9	75% Beef tallow (4.3)	FAS (adjacent)	Systematic (surface)	14 (7)	34 [4](44)	Knowlton et al. 1986
Webb Co., TX (2 areas) March 1985	52		75% Beef tallow (4.3)	FAS (adjacent)	10 Draw-stations (surface)	10 (5)	23 [4](44)	Knowlton et al. 1986
Southern Idaho (2 areas) Jan–Feb 1989	127	0.8	90% Beef tallow (4.3)	FAS (adjacent)	Selective (covered)	21 (1)	60 [4](10) 45 [5](31)	R. D. Nass, unpubl. data
Southern Idaho (4 areas) Dec 1987—Jan–Feb 1989	127–260	1.9	90% Beef tallow (4.3)	FAS (adjacent)	Selective (covered)	21 (1)	34 [4](29) 63 [5](43)	R. D. Nass, unpubl. data
Southern Idaho (2 areas) Jan–Feb 1989	127	7.7	90% Beef tallow (4.3)	FAS (adjacent)	Selective (covered)	21 (1)	67 [4](12) 100 [5](22)	R. D. Nass, unpubl. data
Dona Ana Co., NM Jan–Feb 1991	104	1.9	90% Beef tallow (4.3)	FAS (adjacent)	Selective (covered)	20 (4)	29 [4](42) 32 [5](34) 59 [6](34)	F. F. Knowlton and R. D. Nass, unpubl. data

[1] Represents intended bait density, which was probably modified by differential loss of baits to nontarget animals and other factors.

[2] Selective distribution was placement of baits in relation to signs of coyote activity; systematic distribution was placement at specified spacing between baits without regard for coyote activity; draw-stations were carcasses of large animals with 10–40 baits placed nearby.

[3] Half of baits were also covered with fetid lure (commercial coyote-getter bait).

[4] Determined by physiologic marker in sample of coyotes from study area after bait exposure (sample for Knowlton et al. [1986] was prebaiting).

[5] Determined by particle marker (metallic flakes) in sample of coyote feces from study area after bait exposure.

[6] Determined by radioisotopes in sample of coyote feces from study area after bait exposure.

Baiting Strategies

Early field tests to deliver small nontoxic baits to coyotes were hindered by rapid disappearance of baits taken by nontarget animals, especially rodents and birds (corvids) (Linhart et al. 1968, Tigner et al. 1981 unpubl.). Subsequently, alternative methods of bait placement were compared to assess relative consumption by coyotes (table 6) and nontarget species. Baits placed on the soil surface tended to have greater visitation and consumption by coyotes than baits elevated above ground (30–51 cm) on steel wire and baits buried under soil (1–8 cm) in four comparisons (table 6). Servheen (1983) found similar visitation and consumption rates by coyotes for baits covered with indigenous materials (e.g., stones, cattle manure, dried mud) as for baits on the surface (table 6). Elevated baits tended to reduce consumption by rodents (Tigner et al. 1981 unpubl.) and insects (Servheen 1983). Buried and covered baits had less interference from birds but were still susceptible to rodents (Tigner et al. 1981 unpubl., Baril 1982; R. D. Nass, U.S. Department of Agriculture, Denver Wildlife Research Center, unpubl. data). The CLOD was affected significantly less by nontarget species: Stolzenburg and Howard (1989) reported that only 1 percent of 3,321 visiting nontarget animals activated the device.

Twelve field tests were conducted to measure delivery of nontoxic baits to coyote populations during winter on study areas of 52–1,700 km^2 (table 8). Because no coyotes were removed from the study areas during the bait exposure period, the tests simulate conditions for delivery of oral contraceptives or vaccines. A variety of baits and odor attractants, bait densities, and distribution, placement, and application procedures were employed (table 8). Various particle (metallic flake) and physiologic (tetracycline, mirex, IA, rhodamine B, radioisotope) markers (Savarie et al. 1992) were used to identify individual coyotes that ingested baits on the study areas. All baits were distributed on study areas from the ground either (1) selectively in relation to signs of coyote activity, (2) systematically spaced without regard for coyote activity, or (3) near draw-stations composed of large animal carcasses, which was a traditional method to attract coyotes for delivery of toxicants (Robinson 1948). Linhart et al. (1968) had made several bait applications with fixed-wing aircraft earlier but concluded that aerial distribution was not conducive for effective placement in relation to coyote activity.

The eight field tests during 1966–85 resulted in delivery of baits to only 9–34 percent of coyotes on study areas, based on presence of physiologic markers in samples of coyotes collected by trapping and aerial shooting (table 8). However, Knowlton et al. (1986) delivered baits to 50 percent of coyotes on their two study areas by a combination of three bait distribution methods (systematic, draw-stations, and near water). The four field tests that presented baits at carcass draw-stations resulted in relatively low delivery to coyotes (9–27 percent), a result likely related to territorial spacing patterns that restricted access to the draw-stations (Bowen 1981, Windberg and Knowlton 1988).

During 1987–91, field tests in winter on eight areas in southern Idaho, U.S.A., (R. D. Nass, unpubl. data) and one area in New Mexico (F. F. Knowlton and R. D. Nass, U.S. Department of Agriculture, Denver Wildlife Research Center, unpubl. data) achieved bait delivery to 29 to 67 percent of coyotes, based on presence of physiologic markers (table 8). All of those tests employed selective distribution of covered tallow baits with an adjacent odor attractant at three bait densities on relatively small areas. The greatest success in bait delivery was achieved at the highest density (7.7 baits/km^2). For the study in New Mexico (1991), estimates of coyotes that ingested baits based on presence of physiologic (29 percent) and particle (32 percent) markers were lower ($P < 0.03$) than the estimate based on presence of radioisotopes in feces (59 percent). Therefore, it appears that both types of estimates for percent coyotes that consumed baits during most of the preceding field tests may be biased low. The presence of particle markers probably underestimated coyotes that ingested baits because they were only present in fecal passages for a limited time whereas radioisotopes were detectable for several months (Savarie et al. 1992). The biases associated with the capture of coyotes (Windberg and Knowlton 1990) to examine for the presence of physiologic markers may differ from biases in acceptance of baits.

The effect of multiple bait applications in improving bait delivery was difficult to assess among the field tests because of differences in other variables (table 8). However, the use of different radioisotopes in the initial versus three replacement bait applications on the New Mexico area (1991) provided evidence suggesting that coyotes were more prone to ingest baits after their initial acceptance (F. F. Knowlton and R. D. Nass, unpubl. data).

Two field tests provided data for bait acceptance in relation to age and social (territorial) classification of coyotes. In southern Texas (1985), 88 percent of eight juvenile (1-year-old) females ingested baits compared with 42 percent of 35 adults (F. F. Knowlton, unpubl. data). In New Mexico (1991), 50 percent of eight young (1- to 2-year-old) coyotes ingested bait compared with 24 percent of 34 older individuals (F. F. Knowlton and R. D. Nass, unpubl. data). In southern Texas (1985), 36 percent of 14 territorial females and 21 percent of 19 nonterritorial females had ingested baits from a systematic distribution (F. F. Knowlton, unpubl. data). Similarly, 31 percent of 13 territorial coyotes and 25 percent of 12 nonterritorial coyotes ingested baits from selective distribution at the same bait density (table 8) in New Mexico (1991) (F. F. Knowlton and R. D. Nass, unpubl. data).

The combined data from the two studies indicated greater vulnerability for young coyotes to ingest baits than adults ($P < 0.01$) but no difference in vulnerability between territorial and nonterritorial coyotes ($P = 0.36$). However, 29 percent of territorial females ingested baits placed near draw-stations in southern Texas compared with only 5 percent of nonterritorial females ($P = 0.07$) (F. F. Knowlton, unpubl. data). This result suggests that that bait-distribution method may offer greater selectivity for territorial coyotes.

The progression of research summarized above offers some guidelines for bait application procedures that can improve bait delivery to coyotes. In general, selective distribution of covered (hidden) fat-based baits with an odor attractant at relatively high densities (or application rates) in locales and seasons with minimal interference by nontarget animals should be most effective.

Interest in reproductive inhibition of coyote populations has waned owing to marginal success in delivery of baits (Linhart et al. 1968) and lack of a selective and effective antifertility agent (Stellflug and Gates 1987). Development of a selective immunocontraceptive for canids may overcome the latter obstacle. Till and Knowlton (1983) speculated that contraception may offer a selective method for reduction of coyote predation on livestock because it might remove a major motivation (i.e., feeding litters of young offspring) that often triggers depredations. Because breeding coyotes are primarily territorial adults (Knowlton et al. 1986, Crabtree 1988, Windberg 1995), baiting strategies for delivery of contraceptives must be selective for that cohort of populations in order to be effective. An epizootic of rabies in coyotes and domestic dogs in southern Texas that began in 1988 has stimulated interest in the delivery of an oral rabies vaccine to coyotes via baits (K. A. Clark, pers. comm.) and hence has renewed efforts to improve baits and baiting strategies for this species.

Dingo *(Canis lupus)*

Dingoes, along with wild dogs and their hybrids, are considered a significant economic threat to livestock enterprises in Australia. The application of single-dose toxic (strychnine and Compound 1080) baits has been one of the traditional methods for controlling dingo depredations and remains a contemporary cost-effective and publicly acceptable practice. The use of toxic baits for dingo control began during the mid-1800's in Australia (Rolls 1969). Guidelines for the preparation and ground placement of toxic baits were published in 1934 (Arnold and Herbert 1934). Aerial distribution of baits began in 1946 in Western Australia (Tomlinson 1954, Rolls 1969) and in the 1960's in New South Wales, Australia (Rolls 1969, Thompson et al. 1990).

Current procedures for dingo control vary with the relative risks to livestock and nontarget species, and State governmental agencies provide guidelines for use of toxic baits (Hogstrom 1986, Begg and Davey 1987, Allen 1988, Downward and Bromell 1990, Thomson 1990). Generally, ground placement is used in more accessible areas and aerial application in the expansive or inaccessible regions of Australia.

Research to evaluate and improve the efficacy of bait delivery has been pursued (Hogstrom 1986). The implications for oral vaccination of dingoes for rabies control, if required, were explored by Thomson and Marsack (1992) and Fleming et al. (1992a). There has been no effort to deliver oral contraceptives to dingoes, and the comprehensive assessments of the potential for fertility control among various species in Australia by Bomford (1990) and Caughley et al. (1992) identified substantial limitations.

Baits and Odor Attractants

Two basic types of baits are used for delivery of toxicants to dingoes: fresh-meat baits and standard factory baits manufactured by the Agriculture Protection Board of Western Australia. Preparation of meat baits varies among States but, typically, fresh beef is cut into cubes of 100–250 g and injected with toxicant (Thomson 1986, Eastman and Calver 1988, Allen et al. 1989). In Western Australia, meat baits are partially dried in sunlight for 12 to 24 hours before injection to provide a firm dark skin that reduces attraction to insects (Thomson 1986, Eastman and Calver 1988). Factory baits are 6-g cubes (19 mm on a side) composed of 84 percent beef crackle (rendered fat) with glycerine (moisturizer), gelatin (binding agent), whale oil (odor attractant), a bactericide, fungicide, insect repellant, and the toxicant (Thomson 1986, Eastman and Calver 1988).

McIlroy et al. (1988) stated that fresh-meat baits were traditionally preferred over factory baits for wild-dog control in eastern Australia. Thomson (1986) incorporated plastic marker pellets into baits and documented dingoes' preference for meat baits over factory baits in Western Australia. Hogstrom (1986) suggested that the smaller size and unfamiliar odor of factory baits may make them less attractive than the larger and more familiar portions of fresh meat. Allen et al. (1989) compared the relative attractiveness and palatability of the two standard baits using modified scent-station procedures (Linhart and Knowlton 1975) in southern Queensland. Dingo visitation at their bait stations did not differ between fresh-meat and factory baits, but consumption was greater for meat baits. Allen's group also found that meat baits buried under 2 to 5 cm of soil were equally attractive and palatable to dingoes as those placed on the surface.

Several studies of baiting efficacy showed rapid disappearance of baits. Best et al. (1974) reported that 92 percent of 250 and 77 percent of 270 fresh-meat baits disappeared after 1 day on 2 study areas near Alice Springs, Northern Territory. Dingoes took most baits (58 percent); birds (37 percent) and foxes (5 percent) removed the others. McIlroy et al. (1986a) reported rapid disappearance of fresh-meat baits (69 percent of 275 in July 1980 and 87 percent of 304 in June 1981) after 4 days' exposure near Tumut, New South Wales, with foxes and birds removing most baits. In Kosciusko National Park, New South Wales, 92 percent of 160 fresh-meat baits were removed by nontarget animals (mainly foxes and birds) after 4 days in April 1982 (McIlroy et al. 1986b). In southern Queensland, nontarget animals removed more fresh-meat baits than factory baits (Allen et al. 1989). Allen's team also found that buried meat baits were lost to nontarget species significantly less than baits on the surface.

Interest in improving the efficacy of dingo control has recently stimulated research on odor attractants for use with baits. Mitchell and Kelly (1992) compared visitation rates and behavioral responses of dingoes to eight different attractants using scent-station procedures in southern and central Queensland. Jolly and Jolly (1991, 1992a) used captive dingoes to screen the attractiveness of 53 synthetic compounds and conducted field trials to validate data from the pen studies. Additionally, Jolly and Jolly (1992b) studied the food-finding ability of captive dingoes and suggested that acceptance may be greater for baits that are most recognizable as food.

Baiting Strategies

Ground distribution of dingo baits is typically by selective placement near signs of activity along unimproved roads and near sources of water (Thomson 1990). Aerial distribution is also selective by releases at regulated rates along identifiable dingo travel routes based on terrain features (Allen 1988, Thompson et al. 1990, Thomson 1990). A study of aerial placements using simulated baits (bags of lime) from a helicopter and fixed-wing aircraft was conducted to quantify baiting accuracy and provide guidelines for efficient application (Thompson et al. 1990). A subsequent study assessed the cost-effectiveness of aerial application of dingo baits (Thompson and Fleming 1991).

The early use of toxic baits to control dingoes was justified by circumstantial evidence suggesting its efficacy, such as perceived reduction of populations or declines in livestock losses and bounty payments (Rolls 1969, Newsome et al. 1972). Some initial attempts to assess baiting efficacy in reducing dingo populations were unsuccessful owing to complications with the bait or toxicant (Newsome et al. 1972, Best et al. 1974, McIlroy et al. 1986a). Fourteen field tests of baiting efficacy during 1971–93 resulted in variable dingo mortality (table 9). The greatest reductions in dingo abundance (78–100 percent) were achieved by aerial distribution of fresh-meat baits (Thomson 1986, Thomson and Marsack 1992, Fleming 1994; P. C. Thomson, pers. comm.). Reduction in dingo abundance was generally less for applications of factory baits (table 9), and Thomson and Marsack (1992) had greater reductions with applications of fresh-meat baits 4–5 weeks after distribution of factory baits on the same areas during two trials (44 percent *v.* 31 percent; 63 percent *v.* 6 percent).

Based on mortalities of radio-collared dingoes following bait distribution, Thomson (1986) determined that young and lone individuals were more vulnerable to bait consumption than adults or members of social groups. During his field tests of baiting efficacy in May and October 1980, all of 11 radio-marked dingoes <2 years old were killed compared with 6 of 13 that were ≥2 years. Thomson (1986) speculated that young and lone dingoes may have been most vulnerable because their poorer success in hunting large prey predisposes them to consume baits. No differential vulnerability to baiting between sexes was detected. Thomson (1986) considered the factors most influential in baiting efficacy to be the (1) number and distribution of baits, (2) bait type, and (3) age and social status of dingoes.

Domestic Dog *(Canis lupus)*

Large numbers of unvaccinated free-ranging dogs, both owned and unowned, are a major factor contributing to the lack of effective rabies control in many developing countries (World Health Organization 1988b, Joshi and Bögel 1988). Dog ecology studies conducted during the last 10–20 years (e.g., as summarized in World Health Organization 1984, 1988a, and 1994) have been helpful in furthering the development of oral vaccination for this species. A selective review of dog ecology in relation to rabies has been provided by Wandeler et al. (1993), while several recent dog studies in Africa also have added to our knowledge (DeBalogh et al. 1993, Kitala et al. 1993, Perry 1993). The World Health Organization (WHO) (1988b, 1989, 1991, 1992, 1993b, and 1994), and WHO and the World Society for the Protection of Animals (1990) have provided guidelines for developing oral vaccination of dogs that encompass, among other topics, development of vaccine baits, techniques for evaluating their efficacy, and baiting strategies to maximize bait ingestion by targeted dog populations. These reports also have summarized the results of WHO-coordinated studies and research by private industry.

Until recently, efforts to develop baits for dogs largely borrowed from earlier wildlife studies, and almost all the baits evaluated were those previously developed for red foxes and raccoons (Perry 1989). Using a fox bait described by Winkler and Baer (1976), Baer (1976) was apparently the first investigator to test a vaccine-laden bait with dogs. The bait consisted of a sealed plastic straw containing rabies vaccine that was inserted into a commercially avail-

Table 9. Field tests of efficacy of toxic baits in reduction of dingo abundance in Australia

Location and time	Size of area (km^2)	Type of bait	No. of baits	Bait distribution method	% reduction in abundance	(n)[1]	Reference
Alice Springs, NT Spring 1971	8,681	Fresh meat	520	Near water sources	[2]70		Best et al. 1974
Fortescue River site, WA May 1980	940	Factory bait	12,500	Fixed-wing aircraft	63	(19)	Thomson 1986
Fortescue River site, WA Oct 1980	940	Fresh meat	3,280	Fixed-wing aircraft	100	(18)	Thomson 1986
Fortescue River site, WA Oct 1981[3]	3,300	Factory bait	25,000	Fixed-wing aircraft	31	(13)	Thomson 1986
Fortescue River site, WA Sept 1984	1,500	Fresh meat	6,000	Fixed-wing aircraft	85	(13)	Thomson and Marsack 1992; P. C. Thomson, pers. comm.
Kosciusko National Park, NSW Apr 1982		Fresh meat	160	Selectively along roads	22	(9)	McIlroy et al. 1986a
Nullarbor Plain site, WA Oct 1984	1,600	Factory bait	10,000	Near water sources	29	(17)	Thomson and Marsack 1992; P. C. Thomson, pers. comm.
Nullarbor Plain site, WA May 1985[4]	1,600	Factory bait	25,000	Near water sources	6	(16)	Thomson and Marsack 1992; P. C. Thomson, pers. comm.
Nullarbor Plain site, WA Oct 1986	1,600	Fresh meat	6,200	Near water sources	80	(15)	Thomson and Marsack 1992; P. C. Thomson, pers. comm.
Nullarbor Plain site, WA Oct 1986	750	Factory bait	25,000	Near water sources	78	(9)	Thomson and Marsack 1992; P. C. Thomson, pers. comm.
Taunton Science Reserve, QU 1987	115	Fresh meat	441	Systematically along roads	[2]65		Tierney and Strong 1989
Northeastern New South Wales Apr 1991	151	Fresh meat	3,880	Helicopter	[2]90		Fleming 1994
Northeastern New South Wales Apr 1992	151	Fresh meat	3,040	Helicopter and ground[5]	[2]72		Fleming 1994
Northeastern New South Wales Apr 1993	151	Fresh meat	3,380	Helicopter	[2]78		Fleming 1994

[1] Determined by mortality of radio-collared dingoes following application of toxic baits (except as noted); number of marked individuals in parentheses.

[2] Determined by counts of dingo tracks on treated area before and after baiting.

[3] Aerial application of 4,000 fresh-meat baits on same area 4 weeks later resulted in 44-percent reduction of 9 radio-collared dingoes.

[4] Aerial application of 3,000 fresh-meat baits on same area 5 weeks later resulted in 63-percent reduction of 8 radio-collared dingoes.

[5] Seventy-four percent of baits were distributed by ground placement.

able sausage. In Zimbabwe, a bait that had been initially developed in Canada for red foxes was tested on dogs by Perry et al. (1988). It consisted of a polyurethane sponge cube saturated with a liquid placebo vaccine (egg yolk, molasses in water, and dye marker) that was distributed with a fermented odor attractant to enhance bait discovery. A preformed cigar-shaped bait of boiled and deep-fried cornmeal was used to administer liquid canine adenovirus vaccine to confined dogs (Baer et al. 1989). The adenoviruses are of interest as potential virus vectors for a recombinant rabies vaccine.

A chicken-head bait, originally used for red foxes, was tested with suburban dogs in Tunisia, while a German-manufactured bait ("Tübingen") and a bait of local sausage ("Köfte") have been tried in Turkey (World Health Organization 1991 and 1992). Also in Tunisia, household dogs were tested with four bait types: a sausage bait made of donkey meat and cooked rice, the DuPont polymer fishmeal bait (Hanlon et al. 1989), a chicken-head bait, and a polyurethane sponge bait inside a plastic packet (similar to the Canadian sponge bait) that also contained a fermented odor attractant (World Health Organization 1991, Kharmachi et al. 1992). Three of the above four baits were originally developed for vaccinating red foxes and raccoons. Four different candidate dog baits developed earlier for wildlife were tested in rural Mexico (World Health Organization 1991, Frontini et al. 1992). Two consisted of cylindrical corn, milk and egg batter-coated polyurethane sponge baits (Linhart et al. 1991), both deep-fried in either corn or fish oil and then air-dried. The other two baits were the DuPont polymer fishmeal bait and the Canadian tallow–wax chicken-flavored bait containing a blister pack (Bachmann et al. 1990). A commercially produced dog biscuit was used as a standard or control food item.

Development and field evaluation of baits and baiting strategies for dogs have recently received much more attention and although much of this work has not yet been published, summaries have been provided in World Health Organization documents. The chicken-head bait and polymer fishmeal bait have been compared at a waste-disposal site in northern Tunisia. As measured by visitation to tracking stations, the number of chicken-head baits picked up was estimated to be over seven times that for fishmeal baits (World Health Organization 1993b). An artificial bait made by Virbac Laboratories (Carros, France) for delivering SAG-2 vaccine has been described. It consisted of a solid core containing the vaccine in freeze-dried form. The core had hydrophilic properties and was coated with a protective envelope having hydrophobic properties and food substances attractive to dogs. The core was later modified to make it softer and more porous so as to enhance vaccine release. Several different prototypes of these baits containing biomarkers were tested using owned dogs in Tunisia where their acceptance was compared to that for chicken heads. Artificial bait acceptance rates varied from 24 percent to 60 percent; for the chicken-head bait, acceptance was 59 percent. One of the artificial bait types was compared with chicken heads at a waste disposal site in Tunisia. The same bait was evaluated by house-to-house trials in two semirural areas of Tunisia. Of >300 dogs offered the bait, 84.7 percent completely consumed it (World Health Organization 1994).

In Egypt, the bait preferences of farmer-owned dogs were determined following bait tests in the United States using confined laboratory beagles and mixed-breed dogs. In general, all three groups of dogs showed preferences for baits coated with either tallow, egg, cheese, or poultry products. Polymer fishmeal baits were less preferred by all three groups of dogs. Acceptance by Egyptian dogs of a polymer-bound commercial dogfood-meal bait coated with beef tallow and a dry cheese product was nearly identical to that of chicken-head baits (World Health Organization 1994, Linhart and Wlodkowski 1994).

Four bait types were evaluated in Nepal using both household and free-ranging dogs. Paired bait preference tests showed that a chicken-head bait was preferred over two Canadian blister-pack bait types (chicken or beef flavored) as well as a cylindrical dog-biscuit bait. A potential vaccination rate of 64 percent was estimated for chicken heads given to free-ranging dogs of unknown ownership (World Health Organization 1994).

In Turkey, tests of both the chicken-head bait and the Köfte bait (minced meat) were continued with baits targeted for free-ranging street dogs. A field test of an oral rabies vaccine was conduced wherein of 1,089 dogs that took baits, one-third took the chicken-head bait initially offered and the remaining two-thirds subsequently took the Köfte bait. As determined by dye marker, 28 percent of the vaccine capsules within baits were swallowed and 72 percent were punctured. Larger capsules were ruptured more frequently than smaller ones, and the latter were more often swallowed. Field trials also were conducted in Istanbul to determine the advantages and limitations of daytime *v.* nighttime baiting of free-ranging dogs (World Health Organization 1994).

The factors and requirements associated with delivering vaccine baits to dogs in Africa have been discussed and the African baiting trials summarized. Recommendations for the future distribution of baits and research still needed were presented by Perry and Wandeler (1993). Alternative methods for developing and evaluating dog baits and the various distribution techniques have been reviewed by Linhart (1993). Table 10 summarizes the results of earlier dog bait studies, but specific details of the more recent investigations have not yet been published.

Guidelines for evaluating bait delivery techniques have been compiled by the World Health Organization (1993b and 1994) and Matter (1993). These guidelines assume that candidate dog baits have been tested and shown to be well accepted by dogs under field conditions. The guidelines recommended that initial trials be conducted in towns or villages having 5,000–10,000 inhabitants and $\geq$ 500 dogs. The sequential field trials recommended were (1) a bait test using placebo vaccine (one or more systemic and/or topical markers) to determine dog acceptance and bait contact rates; (2) tests of baiting efficacy determined by providing dog owners with baits at central sites and having owners feed the baits to their dogs at home. Efficacy or probable vaccination rates would be determined by subsequent testing of these dogs for a systemic seromarker incorporated into baits; (3) door-to-door bait distribution to owned dogs in conjunction with estimating dog populations via "capture–mark–recapture" techniques; (4) overnight bait placement for free-ranging dogs; and (5) costs associated with both house-to-house and overnight bait distribution. The so-called handout method, that of offering baits to free-ranging street dogs as they are encountered, also has been mentioned as an alternative strategy.

Recent advances in bait testing and the results of vaccine safety and efficacy trials have led the World Health Organization to announce that field tests to vaccinate dogs orally will be initiated in Tunisia, Turkey, and southern Africa during 1995 (Anonymous 1994).

Raccoon Dog *(Nyctereutes procyonoides)*

Raccoon dogs, originally restricted in their distribution to eastern Asia, were introduced into the European and Asian parts of Russia in the first half of this century. This species subsequently spread over large parts of Eastern Europe and Finland (Anonymous 1984, Cherkasskiy 1988, Helle and Kauhala 1991). The species has accounted for a significant proportion of the rabies cases in eastern European countries since the 1960's. However, it was not until April 1988 that the first case was reported in Finland. At that time, Finland had been free of rabies for almost 30 years (Nyberg et al. 1992). Given the success of oral vaccination of foxes against rabies in Central Europe, Finnish authorities embarked on trials aimed at immunizing both raccoon dogs and red foxes. Because the Tübingen bait (see red fox account) was the only commercially available bait at that time, Tanskanen et al. (unpubl. data) tested these baits with various doses of SAD B19 live attenuated rabies vaccine in captive raccoon dogs. Test animals accepted the baits, and most developed neutralizing antibodies against rabies and survived a subsequent challenge with virulent rabies virus. Thus, there was little incentive to develop alternative bait types. Less than 6 months after the first rabies case was reported, 36,000 baits were distributed by some 800 hunters over an area of 2,400 km^2; an additional 4,500 baits were dropped by a fixed-wing aircraft in a less accessible area of

Table 10. Baits tested for delivery of oral rabies vaccines to domestic dogs (1975–92) (from Linhart 1993)

Bait types tested	Size	Type of test	% of baits bitten or chewed by dogs	% of baits completely ingested	% of dogs marked with placebo vaccine[1]	Reference (location of study)
Slim Jim® sausage	13 cm long	Laboratory dogs	—		—	Winkler and Baer 1976, Baer 1976
Polyurethane sponge cube in plastic sachet with fermented attractant[2] in outer bag	2 × 3.5 × 5 cm	Farms—free-ranging dogs	79 (65/82)	—	25 (138/553)	Perry et al. 1988 (Zimbabwe)
Cooked preformed cornmeal deep-fried in corn oil	"cigar-shaped" cylinder, 10 cm long	Farm-owned dogs	—	100 (11/11)	—	Baer et al. 1989 (Zimbabwe)
Chicken head	—	Suburban-owned dogs Unowned dogs	— —	78 (?) 56 (10/18)	78 (?) 56 (?)	World Health Organization 1991 (Tunisia)
Cylindrical polyurethane sponge containing cornmeal, egg, and milk, deep-fried in:		Rural towns—owned dogs				Frontini et al. 1992 (Mexico)
corn oil	1.5 × 5.5 cm		88 (45/51)	67 (34/51)	—	
fish oil	1.5 × 5.5 cm		85 (33/39)	69 (27/39)	—	
Dupont polymer fishmeal	2 × 3 × 5 cm		90 (43/48)	50 (24/48)	—	
Canadian blister pack (wax)	2 × 3.5 × 3.5 cm		44 (17/39)	10 (4/39)	—	
Small dog biscuit (control)	1 × 2.3 × 4.5 cm		97 (171/176)	88 (155/176)	—	
Sausage of minced donkey meat and cooked rice	7–10 cm long	Owned dogs	56 (28/50)	—	46 13/8)	Kharmachi et al. 1992 (Tunisia)
Dupont polymer fishmeal	2 × 3 × 5 cm		80 (40/50)	—	78 (31/40)	
Chicken head	—		96 (48/50)	—	98 (47/48)	
Polyurethane sponge cube in plastic sachet with fermented attractant[3]	?		66 (33/50)	—	30 (/10/33)	
1/2 Large dog biscuit	15 × 5 × 5.5 cm	Rural towns—owned dogs	—	81 (108/134)	—	Linhart et al, unpubl. data (Mexico)
Cylindrical polyurethane sponge containing cornmeal, egg, and milk, deep-fried in corn oil	1.5 × 5.5 cm		—	84 (111/133)	—	
As above but shorter length	1.5 × 3 cm		—	83 (108/130)	—	
Length of beef hotdog, dried and hardened	1.5 × 4.5 cm		—	77 (104/136)	—	

[1] Numerals in parentheses are dogs positive over total dogs checked.

[2] Attractant consisted of fermented meat, offal, fish, blood, cheese, and yeast; 5 mL placed in outer bag.

[3] Attractant consisted of fermented minced meat, eggs, yogurt, fish, and cheese.

225 km^2. A bait disappearance rate was obtained from 240 monitored baits. On days 4, 8, and 12, 12 percent, 31 percent, and 51 percent of the baits had disappeared, respectively. Tooth marks in empty blister packs recovered from the field suggested that raccoon dogs and foxes were the major consumers. This was later confirmed by demonstration of tetracycline in the lower jaws of 79 percent of 126 raccoon dogs and 88 percent of 56 foxes collected 1–7 months after the campaign, as well as with serologic data (Nyberg et al. 1992). As tetracycline marks were relatively faint in raccoon dogs, the dose per bait was adjusted to 300 mg in later campaigns (B. Westerling, pers. comm.). Finland has not reported any cases of rabies since February 1989, but it has continued its vaccination program along the border with Russia, where rabies is still endemic (Westerling 1993).

Raccoon *(Procyon lotor)*

Baits have been used to deliver toxicants, administer candidate oral contraceptives, and orally vaccinate raccoons against rabies. Fresh eggs were injected with a strychnine, honey, dye, and water mixture and used in past decades to destroy raccoons where rabies was a problem; two poisoned eggs were placed at each bait station (Lewis 1975). Eggs containing a tetracycline biomarker were distributed on a South Dakota study area in late summer to determine the percent of the population that might be reached by an oral contraceptive. Of the raccoons collected during the following 7 months, 87 percent were positive for the marker (Nelson and Linder 1972).

An epizootic of raccoon rabies that began in the mid-Atlantic States during the early 1980's, and European successes with oral rabies vaccination, provided the impetus for a number of laboratory and field baiting studies aimed at delivering oral vaccine to this species. C. E. Rupprecht and associates (Wistar Institute, Philadelphia, PA, U.S.A.), with the collaboration and expertise provided by D. H. Johnston (Ontario Ministry of Natural Resources, Maple, ON, Canada), offered captive raccoons more than 30 fruit, vegetable, and beef/poultry/fish oil extracts and slurries as candidate attractants using a "smorgasbord" testing protocol. Five attractants were then selected and field-tested in conjunction with a 3- × 3- × 4-cm polyurethane sponge bait covered with beef tallow and wax (Johnston and Lawson 1987, Bachmann et al. 1990). The above bait with placebo vaccine (tetracycline) and candidate attractant was placed inside a polyethylene bag and aerially dropped into five 4-km^2 Pennsylvania study sites at a density of 120 baits/km^2. Of the raccoons collected from the study sites, 36–76 percent had eaten one or more baits as indicated by tetracycline-induced fluorescence in the teeth (Rupprecht et al. 1987).

This type of bait also was used to administer candidate vaccine to captive raccoons (Rupprecht et al. 1986), and to subsequently assess experimental field delivery of placebo vaccine near Washington, DC, U.S.A. (Hadidian et al. 1989) and in Virginia, U.S.A. (Perry et al. 1989). The above bait with IA as a seromarker (Larson et al. 1981) was placed in a section (0.8 km^2) of Rock Creek Park, Washington, DC, in June 1986. The wax–tallow coating in which baits were dipped contained 150 mg of tetracycline hydrochloride (THC) per bait. A single bait and 10–20 mL of a ground mackerel–water slurry were placed in a 17- x 24-cm plastic bag and distributed by hand at 15-m intervals along 43 transects at a density of 1,240 baits/km^2. The mackerel–water slurry attractant was selected because it previously had been found to be effective; i.e., raccoons showed no preferences among mackerel, grape jelly, cod liver oil, feta cheese, fresh banana, and beef gravy attractants. Of the raccoons captured during a 3-week posttreatment period, 63 percent had eaten one or more baits (Hadidian et al. 1989).

The Virginia field trial was conducted following laboratory evaluation of 11 candidate bait or attractant combinations (hot dogs, marshmallows, doughnuts, gelatin, molasses, and apple butter). Polyurethane sponge baits were tested both with and without containment in plastic bags or aluminum foil. Candidate food attractants were field-tested using a series of 13 smorgasbord acceptance tests on 2 study areas, 1 located in the coastal plain and the second in the piedmont region of Virginia. Investigators formulated sponge baits that contained a mixture of egg yolk, molasses diluted in water, and 200 mg of tetracycline per bait. They were used for a field trial in which baits and about 10 g of fish-based attractant (canned sardines and soybean oil used to deep-fry fish) contained in an outer bag were dropped from a fixed-wing aircraft on 2 4-km^2 sites at 120 and 450 baits/km^2. Analysis of captured raccoons for tetracycline revealed that between 30 and 73 percent of the animals had eaten one or more baits (Perry et al. 1989).

Field tests were subsequently conducted on Parramore Island, a barrier island in Virginia (Hanlon et al. 1989), where several candidate baits, including a commercially extruded cylindrical (3- × 4-cm) polymer fishmeal polymer bait (E. I. DuPont de Nemours Co., Orange, TX) were evaluated (fig. 1). Several tests of the fishmeal bait were conducted using different percentages of fishmeal, fish oil, and 0.5–10 percent of a water-proofing binder, an ethylene vinyl acetate copolymer sold as Elvax^R or Aquabind™ by DuPont and patented by that company as a component of a long-lived, semiartificial, water-borne feed (Smith and Daigle 1988). The above study also compared raccoon acceptance of the polymer fishmeal bait to three other baits, the Canadian polyurethane sponge bait mentioned earlier, a Canadian sachet or blister-pack bait (Bachmann et al. 1990), and a bait designated as the "German sachet" or "Tübingen" bait (Schneider et al. 1988). The latter three baits had been originally developed for the red fox. Hanlon's team compared the above baits by placing each type 0.3 m apart in a smorgasbord grid pattern and randomly changing their positions following each trial. Raccoons were found to consume the polymer fishmeal baits more completely than the other three bait types. Paired bait tests also were conducted to compare removal of baits in plastic bags, baits without bags, and molasses-enriched baits. A final field trial involved placing baits in small plastic bags overlaid with a fish-based slurry (vegetable oil and salmon) every 30 m along transects (920 baits/km^2). Bait disturbance was high (80–100 percent), primarily by raccoons, as revealed by tracking stations. Biomarker analysis of raccoons captured on Parramore Island, VA, also was encouraging (Hanlon et al. 1989).

A subsequent Parramore Island test provided additional information. A candidate oral rabies vaccine (V–RG) was placed in a wax ampule that was inserted into a polymer fishmeal bait. The bait was then placed inside a plastic bag that contained approximately 50 mL of a slurry to enhance bait discovery and consumption. Baits were placed out on foot at 12- to 30-m intervals along linear transects, resulting in a density of about 1,000 baits/km^2. The presence of biomarkers in captured raccoons, tetracycline in teeth and bone, and sulfadimethoxine (SDM) in serum, revealed that 78 percent (38/49) to 84 percent (47/56) of raccoons from the two treatment areas had consumed one or more baits (Hanlon et al. 1993, Rupprecht et al. 1993a).

Field trials also were concurrently conducted on two barrier islands off the coast of South Carolina, U.S.A. (Murphy and South islands). Tracking stations placed at 0.1-km intervals (Linhart and Knowlton 1975) were used to compare raccoon visitation rates to different candidate attractants such as raccoon urine, synthetic fermented egg (Bullard et al. 1978), and commercially available essences or odor attractants such as persimmon, sweet corn, shellfish, and shrimp. A mixture of blue crab offal, synthetic shellfish oil, sucrose, vegetable oil, and raw eggs was selected for all subsequent baiting trials. The same four bait types Hanlon's team tested on Parramore Island were packaged in perforated plastic bags containing 10–20 mL of the above attractant into which was mixed 300 mg of biomarker, a rhodamine B dye powder. Baits at densities from 200 to 1,000/km^2 were placed by hand along transect lines and near known raccoon dens and their trails along waterways. Bait disturbance rates (all species) were reported as 93–100 percent by 7 days after bait deployment, with bait acceptance rates by raccoons at 49 to 85 percent.

The South Carolina workers (Hable et al. 1992) suggested that field crews use a minimum baiting density of 500 baits/km^2 in areas having average raccoon densities to achieve a 70-percent or higher acceptance rate but that 700–1,000 baits/km^2 or multiple baitings might be required under less favorable field conditions. Hable et al. stated that the relationship between raccoon density and the level of bait density required to reach 70 percent or more of the population had yet to be determined. They also concluded that the polymer fishmeal bait was superior to the others tested because of its durability, resistance to insect damage, its attractiveness to raccoons, and its potential for commercial production in different sizes and formulations.

The first mainland field trial to determine the safety of the V–RG vaccine was conducted in northern Pennsylvania, where field crews distributed 500 polymer fishmeal baits/km^2 by foot on a 10-km^2 study site that supported a wide variety of nontarget mammals and birds. Only 2 of 150 nontarget individuals comprising 9 different species trapped after baiting were found positive for the biomarker (tetracycline). Of raccoons, 70–85 percent had consumed one or more baits (Rupprecht et al. 1992; C. E. Rupprecht, pers. comm.).

Movement of raccoon rabies into New Jersey, U.S.A., in 1989 stimulated interest in determining the potential for oral vaccination in that State. Bait acceptance trials were conducted in the fall of 1990 using three different baiting densities on three study areas so as to estimate the minimum density of baits required to reach greater than 70 percent of the population. The polymer fishmeal baits used contained three different biomarkers: tetracycline in the bait matrix, IA in a paraffin wax ampule, and SDM in a blue-crab slurry. Baits and slurry were contained within plastic bags dropped by helicopter. Posttreatment raccoon capture revealed that 80 percent of the raccoons were positive for IA at 200 baits/km^2, 44 percent at 100 baits/km^2, and only 1 of 3 raccoons at 50 baits/km^2 (Diehl et al. 1991). Efforts were then initiated to create a barrier or zone of immune raccoons across the Cape May peninsula in southern New Jersey such that the southward spread of rabies would be excluded from the southern tip of the peninsula. More than 89,000 polymer fishmeal baits containing V–RG in wax ampules were dropped by helicopter and placed by hand along roads in three applications (spring–fall–spring) on 559 km^2 (160 baits/km^2) prior to rabies' reaching the vaccination zone. An additional 73,400 baits were subsequently distributed at 4 rabies "hot spots" and in 2 zonewide vaccinations. At tracking stations, 80–87 percent of baits were disturbed, primarily by raccoons, during the first 10 days after bait distribution in November 1993 and March 1994. The percentage of raccoons collected after treatment showing evidence of biomarker varied from 40 to 76 percent, depending upon when they were collected relative to time of bait distribution (Rupprecht et al. 1993b, Roscoe et al. 1993 and 1994). Unlike the Parramore Island, VA, and Pennsylvania tests, which sought to determine vaccine safety, the New Jersey trial was primarily concerned with oral vaccination efficacy, the first such test for the raccoon.

Modest efforts to develop raccoon baiting technology were made by the U.S. Department of Agriculture (Denver Wildlife Research Center, Animal Damage Control, Animal and Plant Health Inspection Service, Denver, CO 80225), during 1987–90. Captive raccoons were used in three-choice bait-preference tests to evaluate a variety of natural and synthetic food attractants. Investigators created a timing device that used analog clocks to record when individual baits were taken from bait trays. Preference could thereby be determined not only by the number of each type of bait consumed but also by the sequence in which baits were selected. These trials identified as preferred bait that consisted of a polyurethane foam sleeve dipped in a commercial food batter mixed with cornmeal, milk, and eggs. The bait was deep-fried in corn oil, and a 2-mL wax ampule for vaccine containment was inserted into the completed bait (Linhart et al. 1991). A field trial of this bait was conducted in spring 1990 on Sapelo Island, GA, where 2,300 baits were distributed from all-terrain vehicles or pickup trucks on 28 km^2 at a bait density of 82 baits/km^2. Subsequent capture of raccoons and evidence of biomarker (IA) indicated that 65 percent of the raccoon population had consumed one or more baits (Linhart et al. 1994).

Efforts by the Ontario Ministry of Natural Resources to develop oral rabies vaccination technology had, until recently, focused on the red fox (see red fox account). However, rabies in skunks, primarily in urban areas, and the movement of the epizootic of rabies in raccoons northward through New York, U.S.A., redirected some research toward the latter two species.

The development of baits and an aerial baiting system evolved over a period of years. Baits developed for foxes and distributed at densities calculated to vaccinate this species also have been ingested by raccoons, a species normally found at much higher densities. In Ontario, aircraft-distributed wax- and tallow-coated sponge baits have reached 74 percent of the foxes and 43 percent of the raccoons. A small trial in Pennsylvania reached 76 percent of the raccoons (Johnston et al. 1988). Bachmann et al. (1990), working in Ontario, stated that bait acceptance by raccoons and skunks was also studied, but his team "did not design specific experiments to optimize acceptance by these species." However, Rosatte et al. (1990) has described a specific skunk and raccoon baiting study in an urban environment (Toronto) that compared two different attractants, chicken "essence" and cod oil, both in a tallow–wax–tetracycline mixture. These investigators found a positive correlation between bait density and raccoon bait acceptance (cod oil baits only) and showed that cod oil baits were better accepted by raccoons than those containing chicken essence. On one area, all blister packs within baits had been chewed and emptied of placebo vaccine, and only one partially eaten bait was retrieved. Sixty-eight percent (34/50) of the raccoons had eaten a bait at a density of 147 baits/0.04 km^2. More recently in Ontario, five attractants were exposed to captive raccoons and two were then field-tested. Both cheese powder and icing sugar plus marshmallow "essence" (ISM) were found to be highly acceptable. Baits containing ISM were aerially dropped on two 150-km^2 plots (50 and 100 baits/km^2) and also hand-placed (200 and 400 baits/km^2) on urban plots. Subsequent capture of raccoons and evidence of tetracycline indicated acceptance rates of 44 percent and 58 percent for 50 and 100 baits/km^2, respectively. However, samples obtained 2 weeks or more after baiting had bait acceptance rates up to 70 percent in the 100/km^2 plot. Additional tests of the above baits were continued in 1994 but results were pending at the time of this writing (Rosatte et al. 1994).

Tests of a new raccoon bait of unspecified ingredients that was used with a biomarker and distributed at a density of 200/km^2 on an urban–suburban site in central New York State have been described. Examination of raccoons after treatment revealed that 70 percent had eaten baits. A trial of the Ontario blister-pack bait, also distributed in similar type habitat, resulted in 91 percent of the raccoons consuming baits (Bigler et al. 1994). Oral rabies vaccination tests have been initiated in eastern New York State to determine if treatment will reduce the numbers of rabid raccoons detected in a baited *v.* unbaited area, both of which are experiencing an outbreak of the disease. The efficacy of two different vaccine containers will also be evaluated (Hanlon et al. 1994).

Recent efforts in Massachusetts, U.S.A., to establish a zone of orally immunized raccoons along the canal dividing the mainland from the Cape Cod peninsula have been summarized. A total of 16,500 polymer fishmeal V–RG vaccine baits were distributed by ground crews and helicopter over a 157-km^2 area. Three sites within the area were each treated differently; variables tested were baiting density and bait placement. Raccoons were collected after treatment and tested for virus neutralizing antibodies; it was found that the percent of antibody-positive raccoons varied significantly (19 percent, 39 percent, and 46 percent) among treatment sites. These data suggested that targeting preferred habitat would be a cost-effective way to vaccinate raccoons orally (Robbins et al. 1994). Table 11 provides a summary of raccoon baiting field trials.

Raccoons may learn to seek supplemental food at baiting sites (Dalgish and Anderson 1979), and a number of animals may visit such sites (Sharp and Sharp 1956, Dalgish and Anderson 1979, Slate 1985, Curran 1988). Competition at a raccoon feeding site has been documented by Nicolaus et al. (1982) and others, but how this might effect the delivery of nonlethal biologics and chemicals is not known. Several investigators have suggested using central baiting sites where raccoons could be concentrated by

Table 11. Summary of published raccoon biomarker uptake during bait efficacy or oral rabies vaccine safety field trials

Location and year	Bait type	Biomarker/ vaccine in bait and samples collected	Distribution method	No. of baits placed	Size of area (km^2)	Bait density (no./km^2)	% bait disturbance[1] raccoon	% bait disturbance[1] all spp.	No. of raccoons marked/ collected (%)	Reference
Central Pennsylvania (5 test areas) 1985	Sponge bait cubes	Oxytetracycline (100–200 mg) teeth	Aircraft	484 ? 484 ? 484 ?	4 4 4	120 120 120	NA[2] NA[2] NA[2]	NA[2] NA[2] NA[2]	5/14 (36) 6/9 (66) 13/17 (76)	Rupprecht et al. 1987
Rock Creek Park, DC 1986	Sponge bait cubes	Iophenoxic acid (5 mg) blood sera	Foot	1,000	0.8	1,240	—	80 (1) 97 (7)	33/52 (63)	Hadidian et al. 1989
Coastal plain of Virginia 1986	Rectangular sponge in plastic film	Tetracycline (200 mg) teeth & adj. bones	Aircraft	481 1,934	two 4-km^2 sites	107 483	— —	26 (3) 33 (3)	7/12 (58) 7/11 (64)	Perry et al. 1989
Piedmont plateau of Virginia 1986	Rectangular sponge in plastic film	Tetracycline (200 mg) teeth & adj. bones	Aircraft	500 2,078	two 4-km^2 sites	133 428	— —	57 (4) 21 (4)	5/8 (63) 11/21 (52)	Perry et al. 1989
Parramore Island,[3] VA (4 test areas)	Polymer fishmeal	Tetracycline (100 mg) & rhodamine B (100 mg) teeth, bones, & scats	Foot	117 26 140 25	0.13 0.02 0.51 0.07	870 1,300 270 340	89 (2) — — —	100 (2) 88 (2) 91 (2) 100 (2)	6/10 (60) 2/4 (50) 2/5 (40) 3/5 (60)	Hanlon et al. 1989
North Island, SC	Polymer fishmeal	Tetracycline (100 mg) bone	Foot	275	0.30	920	—	78 (2)	8/8 (100)	Hanlon et al. 1989
Murphy Island I, SC 1987–88	German fishmeal Canadian chicken	Tetracycline (150–200 mg) teeth & bones	Foot	400	2	200	—	59–99 (2) 93–100 (7)	12/17 (71)	Hable et al. 1992
Murphy Island II, SC 1987–88	Polymer fishmeal	Tetracycline (150–200 mg) teeth & bones	Foot	500	0.5	1,000	—		17/20 (85)	Hable et al. 1992
South Island I, SC 1987–88	Tallow/sponge German fishmeal	Tetracycline (150–200 mg) teeth & bones	Foot	600	2	300	—		19/39 (49)	Hable et al. 1992
South Island II, SC 1987–88	Polymer fishmeal	Rhodamine B (300 mg) teeth & bones	Foot	250	0.5	500	—		11/24 (46)	Hable et al. 1992
Parramore Island, VA	Polymer fishmeal	Tetracycline (150 mg) & sulfadimethoxide (250 mg) bone & sera	Foot	3,120	3.12	1,000	76 (5)	92 (5)	42/53 (79)	Hanlon et al. 1993
Sapelo Island, GA 1990	Corn-flavored sleeve bait	Iophenoxic acid (10 mg) blood sera	Ground vehicles	2,300	28	82	44 (2)	74 (2)	35/54 (65)	Linhart et al. 1994

Table 11—Continued

Location and year	Bait type	Biomarker/ vaccine in bait and samples collected	Distribution method	No. of baits placed	Size of area (km²)	Bait density (no./km²)	% bait disturbance[1] raccoon	% bait disturbance[1] all spp.	No. of raccoons marked/ collected (%)	Reference
Toronto, ON, Canada 1989	Canadian blister, cod oil	Tetracycline (100 mg) teeth	Foot	147	0.04	3,675	—	—	34/50 (68)	Rosatte et al. 1990
Ontario, Canada 1993	ISM[4]	Tetracycline (180 mg) teeth & bones	Aircraft	7,500	150	50	NA[2]	NA[2]	? (44)	Rosatte et al. 1994
Ontario, Canada 1993	ISM[4]	Tetracycline (180 mg) teeth & bones	Aircraft	15,000	150	100	NA[2]	NA[2]	? (58)	Rosatte et al. 1994
Central New York State 1992	Cornell[5]	Iophenoxic acid (10 mg)	Foot	?	?	200	—	—	48/69 (70)	Bigler et al. 1994
Central New York State 1994	Canadian ISM[4] (?)	Iophenoxic acid (10 mg)	Foot	?	?	200 ?	—	—	42/46 (91)	Bigler et al. 1994
Cape Cod, MA 1994	Polymer fishmeal	V–RG blood sera (VNA[6] to rabies)	Foot / aircraft	468 ? 832 ? 988 ?	52 ? 52 ? 52 ?	90 160 190	— — —	— — —	? (39) ? (19) ? (46)	Robbins et al. 1994
Southeastern New Jersey (3 test areas) 1990	Polymer fishmeal	Tetracycline (100 mg) iophenoxic acid (10 mg) sulfadimethoxine (250 mg) bone?, blood sera	Aircraft	268 648 1,166	5.4 ? 6.5 ? 5.8 ?	50 100 200	NA[2] NA[2] NA[2]	NA[2] NA[2] NA[2]	[7]1/3 (33) [7]11/35 (44) [7]47/59 (80)	Diehl et al. 1991
Southern New Jersey 1992–94	Polymer fishmeal	Tetracycline (? mg)	Aircraft/ ground	162,700+ (5 applications)	559	112	?	80–87	17/39 (44) 99/130 (76) 15/23 (65)	Roscoe et al. 1994

[1] Values in parentheses are the number of nights following bait placement when bait disturbance rate was determined.

[2] Not available due to aerial bait distribution

[3] Because of poor tetracycline marking of teeth of Parramore Island raccoons, rhodamine B marking of scats was used to indicate percentage of raccoons eating baits.

[4] Variant of the Ontario blister-pack bait (table 2) made of tallow, microbond wax, mineral oil, icing sugar, and marshmallow essence.

[5] Bait of unspecified ingredients produced at Cornell University as reported by Bigler et al. (1994).

[6] VNA = virus neutralizing antibodies.

[7] Iophenoxic acid data only.

supplemental feeding and then be administered vaccine baits (Slate 1985, Hadidian et al. 1989, Rupprecht et al. 1992, Linhart et al. 1994). This strategy has not been tested so far, although Johnson and Rauber (1970) successfully used permanent feeding stations to administer an anticoagulant on whole shelled corn to raccoons preying upon shorebird and sea turtle nests. These investigators placed covered feeders 25–30 cm above the ground to enhance selectivity and documented reduced raccoon activity following placement of the poisoned corn. Frantz (1994) has described a protective bait station for delivering rabies vaccine baits.

Currently available information and the results of the ongoing investigations summarized above should soon provide a wealth of data as to how baits and baiting strategies can be used to deliver orally effective biologicals to raccoons. However, data are still lacking to demonstrate that oral vaccination of this species can effectively reduce or eliminate rabies over large geographic areas. Furthermore, to our knowledge, no one is presently investigating oral contraception for the raccoon.

Striped Skunk *(Mephitis mephitis)*

Toxic baits made of meat, tallow, or egg have been used in south central Canada and in the central region of the United States to reduce striped skunk populations where this species was a carrier of rabies (Gremillion–Smith and Woolf 1988). Although toxic baits were widely used in the past, only a few studies have critically assessed bait preferences or alternative baiting strategies and only limited efforts have been made to use baits as a vehicle for oral contraceptives or for orally effective rabies vaccines. However, some data on skunk bait acceptance has been acquired as a secondary objective to the application of baits for red foxes, as in Ontario, Canada, for example (Johnston and Voigt 1982, Johnston et al. 1988, Bachmann et al. 1990).

In California, U.S.A., pieces of raw wiener impregnated with strychnine were placed in short sections of 6-inch-diameter pipe to restrict bait uptake by larger carnivores. Bait stations were placed in culverts and hollow logs, beneath bridges, and along irrigated ditches or streambanks (Maynard 1965). Schnurrenberger et al. (1964) used den gassing and strychnine and honey-laced chicken eggs to control skunks in Ohio. In the United States, strychnine-treated eggs also have been used in Montana and elsewhere in the northern prairie region as an emergency measure to control rabies in skunks (Seyler and Niemeyer 1974, Nesse and Seyler 1977). Poisoned eggs were distributed within a 5-km radius of sites where rabies had been diagnosed in skunks. Eggs were placed at skunk dens and holes, dumps, culverts, junkpiles, and unoccupied buildings. Poisoned skunks were most often found within 6 m of baiting sites. Surveillance areas also were established to monitor the distribution of the disease. However, Nesse and Seyler (1977) were unable to determine how effectively such efforts eliminated diseased skunks from baited areas. Efforts were made by the U.S. States of Wyoming and Montana to seek a Section 3 registration for strychnine-treated eggs from the U.S. Environmental Protection Agency (EPA) for controlling rabies in skunks (Thomas 1986). However, registration has not been granted, presumably because the additional data requested by EPA to support the registration were never obtained.

By far the greatest use of baits for controlling skunks has been in Alberta, Canada, when rabies in the Province's fox population was first diagnosed and subsequently spread southward. A massive wildlife control program—aimed primarily at gray wolves *(Canis lupus)*, foxes, and coyotes but also affecting skunks—relied heavily on large numbers of toxic baits made of various fats, tallow, paraffin, and waxes that were melted and poured into cups containing capsules or cubes of toxicant (Ballantyne and O'Donoghue 1954). Similar baits have been widely used in North America and elsewhere for other species. Control efforts in Alberta were later focused on the striped skunk as this species emerged as the primary rabies carrier in south central Canada (Gunson et al. 1978). Chicken eggs (1–5) and bait cubes (beef fat and parawax) were placed in skunk habitat, and uneaten baits were retrieved and destroyed after 10 to 14 days.

Control was concentrated within 5 km of a known rabid animal. Available data suggested that population reduction effectively controlled the disease (Rosatte 1986, Rosatte et al. 1986).

Pybus (1988) extensively reviewed rabies and its control in Alberta and Saskatchewan, Canada, and in Montana and concluded that control efforts (poisoning, den gassing, and trapping) ". . . contributed to limiting the spread and establishment of rabies in striped skunks within prairie habitats." This assessment was in agreement with earlier program reviews (Ballantyne 1958, Gunson et al. 1978, Rosatte et al. 1986).

The use of poisons to control rabies in skunks is currently much more restricted; and, in Canada at least, research efforts are now being directed toward development of recombinant oral rabies vaccines as an alternative technique (Charlton et al. 1992).

Skunk preference for egg *v.* tallow baits was evaluated by Roy and Dorrance (1992), who found higher selectivity for egg bait. There were no significant seasonal differences in consumption of the two baits by skunks and nontarget species, but eggs cannot be used when nighttime temperatures fall below freezing.

Tallow baits were used to deliver a candidate antifertility compound (DES) to a population of wild skunks on a 186-km^2 area in Illinois, U.S.A. Baits (48/km^2) were distributed annually in the spring of 1965 and 1966 near culverts and fence rows and along roadways. More than 88 percent of the baits were taken by all species within 10 days after placement. However, skunk reproductive rates in the treated area and a reference area were not significantly different (Storm and Sanderson 1969).

Another field baiting study in South Dakota used a biomarker (dimethylchlorotetracycline, now commonly known as demeclocycline) in baits to assess the feasibility of delivering antifertility agents to skunks and raccoons (Nelson and Linder 1972). Chicken eggs containing the biomarker were distributed in August and September on a 65-km^2 agricultural area with wetlands at a density of 28.2 eggs/km^2. Sampling of animals from the test area after treatment revealed that 29 percent of the skunks had consumed one or more eggs.

Although the striped skunk has been a major carrier of rabies over much of North America, the technical literature indicates that only limited efforts have been directed at systematically developing efficacious baits and delivery systems for this species.

Small Indian Mongoose *(Herpestes javanicus)*

Of the 37 mongoose species, bait development and use has been reported only for the small Indian mongoose, which was introduced into the Caribbean area during the 19th century. Strychnine-laden baits of smoked herring, salted pork fat, shrimp, fish entrails, "heads of fowl," and eggs were used to control mongooses because of rabies on the island of Trinidad (Urich 1914). On the island of Puerto Rico, bait stations made of open-ended cans containing toxic 57-g sun-dried fish baits were placed at densities of about 250 stations or less per km^2. Mongoose visitation to stations was 18–57 percent with mortality on two test areas estimated at 88–89 percent. All adults (but not young juveniles) were eliminated from an island (1.6×2.4 km) by using fish baits in bait stations placed at a density of 167/km^2 (Pimental 1955).

Toxic baits were used intermittently over a period of years (1950–60, 1973) on the island of Grenada, but Everard and Everard (1985 and 1988) stated that although mongoose numbers were reduced by toxic baits, results were temporary and did not provide a long-term solution to the rabies problem. C. Vargas (pers. comm.) used captive mongooses to test baits for delivering oral rabies vaccines and concluded that polyurethane sponge baits (Linhart et al. 1993) saturated with a 50:50 mixture of raw eggs and corn oil were preferred. Similarly, an egg/corn oil-flavored polyurethane sponge bait and DuPont polymer fishmeal baits (the latter containing different food additives) were all well accepted without apparent preference by mongooses on the island of Antigua. Tracking tiles and a short-term oral biomarker (DuPont oil blue A™ dye) were effective in recording mongoose and nontarget animal bait take and ingestion rates (Linhart et al. 1993). Also on Antigua, polyurethane sponge baits and polymer fishmeal baits distributed by foot along transects on 2 1-km^2 study sites at rates of 400 and 2,000 baits/km^2 marked (THC and DuPont oil blue A™ dye) 42 percent and 60 percent of the mongooses at the low bait density levels and 91 percent at the high bait density. Polymer baits (500 baits/km^2) at central bait stations on a third 0.81-km^2 study site reached 69 percent of the mongooses (Creekmore 1992, Creekmore et al. 1994).

Toxic baits have been used to reduce mongoose numbers because of their predation on game birds and endangered ground-nesting birds. On St. Croix, U.S. Virgin Islands, fresh 8- to 15-cm-long baits using fish, canned fish, fresh beef, canned horsemeat, dehydrated fishmeal, or dogfood were compared for delivery of toxicants to mongooses. Fresh fish baits at a rate of 800–1,200/km^2 were placed early in the morning to reduce nocturnal bait removal by rodents. Ants were estimated to have destroyed 10–20 percent of baits, and incorporation of an insecticide (chlordane) into baits was recommended. A nonremovable ground-meat bait placed inside wooden bait stations to protect it from nontarget species was distributed at 0.2- to 0.4-km intervals (Spencer 1950 unpubl.). In Hawaii, U.S.A., 57-g ground-meat baits containing warfarin were placed in tube-shaped bait stations of hardware cloth located about 90 to 150 m apart (Woodworth and Woodside 1953 unpubl.). Also in Hawaii, diced-meat, ground-meat, and fresh fish baits were compared for administering thallium sulfate to captive mongooses (Kridler 1965 unpubl.). Concern about mongoose predation on the eggs and young of at least eight species of endangered Hawaiian birds led to additional studies (1984–88). Ground-meat baits containing an anticoagulant and protected by bait stations made of plastic pipe placed 250 m apart within 0.25- to 1-km^2 plots have been tested. A 100-percent mortality rate was estimated by monitoring radio-collared mongooses trapped and released within test areas prior to treatment (Keith et al. 1990). No efforts have been made to evaluate oral rabies vaccines or to determine the efficacy of vaccine bait delivery by air to immunize mongooses over large areas.

Feral Swine *(Sus scrofa)*

Toxic baits are extensively used in Australia to control feral swine damaging crops and pastures, fences and watering sites, waterfowl habitat, and native vegetation. Swine numbers are also reduced because they prey upon young lambs and indigenous wildlife species. Concern about the role of feral swine in the maintenance and spread of endemic or exotic diseases has resulted in contingency plans to control their numbers by poison baits (McIlroy 1983).

Grains, grain-based pellets, fruits, vegetables, and meat baits have been used to deliver toxicants to feral swine. Recovery of placed baits following nighttime exposure, the use of dyed baits to reduce scavenging by birds, and burying or covering baits have been suggested as ways to increase their selectivity (McIlroy 1983).

Pretreatment feeding is considered the most important single step for effective ingestion of poison bait. Pretreatment for 3 days or more may be needed to accustom feral swine to novel bait types and to concentrate them prior to poisoning.

Establishment of permanent or semipermanent feeding stations is considered a worthwhile strategy under some conditions. Dead animals (carrion) were found to concentrate feral swine for increased baiting efficacy, and burying fermented grain bait kept it attractive for a longer period than grain placed on the ground surface. Buried bait was also considered less available for nontarget species (Allen 1984).

Wheat, sorghum, and corn were equally accepted by penned feral swine (Kleba et al. 1985); however, another study (O'Brien and Lukins 1988) found that bait type significantly affected uptake rates by free-ranging feral swine and pelleted baits were preferred. Investigators placed bait stations in areas showing signs of feral swine activity, often near water, and used fencing to exclude livestock. Pretreatment feeding was carried out for 3 to 7 days, and the amount of toxic bait subsequently placed was approximately 75 percent of untreated bait uptake (O'Brien and Lukins 1988). Elsewhere in Australia, a poisoned wheat bait was placed at recently rooted areas and at creek crossings, holes in livestock fences, and along animal and vehicle tracks. Bait trails and 1 kg piles of treated grain were laid for 15 days at sites where untreated grain had been previously consumed. Most treated bait was covered with vegetation or fallen branches or buried to reduce uptake by nontarget species (McIlroy et al. 1989). McIlroy's team have suggested that a 95-percent or greater reduction of feral swine in New South Wales would be required in order to eradicate foot-and-mouth disease within a 3-week period.

Hone (1986 and 1992) developed predictive models for poisoning vertebrate pests, especially feral swine, and applied his models to the results of an actual swine poisoning program. He also discussed the use of models both for planning and for evaluating population reduction programs.

Feral swine control in two national parks in Australia and United States was studied by using various indices such as the extent of rooting, track counts, swine feeding on plants, and deposition of feces to measure the success of population reduction programs. Control was implemented on both areas because of extensive damage to and alteration of native vegetation. Partial control was achieved in the Australian park with treated wheat grain following pretreatment feeding of bread, acorns, and wheat for several days. The investigators (Hone and Stone 1989) recommended methods for further reducing feral swine densities.

In another Australian study, water-soaked wheat was applied in piles along trails for 14 days followed by warfarin-treated wheat placed at 69 sites for 57 days on a 94-km^2 study site. A 98.9-percent reduction in swine numbers was achieved; however, an additional 38 animals were removed during the following 12 months (Saunders et al. 1990). Warfarin-treated grain was placed out on two test areas either ad libitum or intermittently over a 14-day period to evaluate baiting frequency. Control was estimated at 61 percent and 35 percent, respectively, with little or no reduction of feral swine on an unpoisoned reference area (Choquenot et al. 1990).

Choquenot et al. (1993) used proportional bait take (i.e., index–manipulate–index) of soaked wheat grain laid in piles and along trails between piles to estimate the percentage reduction of wild pigs by trapping. Proximity to nontoxic wheat bait and hunger appeared to be the primary factors responsible for seasonal differences in bait consumption by feral swine. Trail baiting in the hill country of southeastern Australia was more likely to be effective in late autumn than during other seasons. Bait types (wheat *v.* pellets) and whether or not baits were covered also affected bait uptake by swine and nontarget mammals and birds (McIlroy et al. 1993). Significant factors affecting bait uptake by swine in southeastern New South Wales, Australia, were the locality characteristics relative to vegetative cover, recent swine activity, and season (Saunders et al. 1993). A recent Australian document outlined the conduct of pest control in each State including that for feral swine and proposed national guidelines for future activities (Braysher 1993).

The status of feral swine (Brooks and Ahmad 1993) and use of several candidate toxicants and delivery methods have been evaluated in Pakistan. Dough baits made of wheat flour were left overnight at sites where swine activity had been observed. Bait of whole oats was placed in furrows and lightly covered with soil; another method involved surface placement of treated whole-wheat grain bait after 4 to 5 nights of pretreatment. Wheat grain baits in buried plastic bags and similar baits placed in modified wooden hog feeders were also tested. A cracked-wheat grain bait in sugar-flavored paraffin was placed in soil furrows and checked daily. The advantages and disadvantages of each type of treatment were summarized by these investigators (Brooks et al. 1990 unpubl.).

In the Galapagos Islands, Ecuador, Coblentz and Baber (1987) found that poisoning destructive feral swine that had been introduced onto the islands had the best potential and was the most cost-effective control method of several under consideration. Fifty-nine percent of placebo toxic baits (30 g of goat meat) were eaten following their placement for 2 to 4 days along trails and under vegetation.

Different food baits and olfactory attractants were tested using captive and free-ranging feral swine in the Great Smoky Mountains National Park (Southeastern United States), where swine were adversely affecting native vegetation. Investigators tested 28 candidate attractants in pens and noted swine responses from adjacent observation blinds. Ten attractants and a control were later field-tested using free-ranging feral swine response to attractants placed at tracking stations. The study was flawed by procedural problems and low visitation rates to tracking stations. However, in general, results suggested that feral swine significantly preferred fermented corn mash to other baits, and that there were no significant preferences for the various olfactory attractants (Wathen et al. 1988 unpubl., Peine and Farmer 1990).

Polymer fishmeal baits containing biomarkers were hand-placed in a grid pattern on a 405-ha test site on Ossabaw Island, GA, and uptake by feral swine was found to be rapid: 88 percent of monitored baits were removed within 72 hours. Capture of feral swine after treatment showed that 95 percent had consumed one or more baits (Fletcher et al. 1990). More recently, aerial distribution of polymer fishmeal baits, also on Ossabaw Island, has shown potential (D. Kavanaugh, pers. comm.). These results suggested that delivery of oral vaccines for control of pseudorabies and swine brucellosis may be feasible.

Lastly, efforts are underway to develop baiting methods for delivering oral vaccines to control hog cholera (classic swine fever) in Germany (A. Neubert, pers. comm.) and in France (E. Masson, pers. comm.).

White-Tailed Deer *(Odocoileus virginianus)*

Treated feeds or baits containing vaccines, medications, contraceptives, or biomarkers have the potential for controlling diseases of white-tailed deer, reducing local populations where they are a nuisance or causing damage to agriculture, or for studying deer movement and activity patterns. Little information is currently available as to how these agents might be delivered. Furthermore, not much is known about how seasonal movements, habitat use, behavior, and food preferences of deer might affect acceptance of free-fed treated grains or food pellets. As recently as 1980, Hubert et al. stated that there was a lack of studies aimed at determining use of supplemental rations by high density free-ranging deer populations. Supplemental feeding of deer with a goal of improving hunting success is a common practice, but few data are available that relate such feeding to the oral administration of chemical or biologic agents. In theory at least, the various types of automatic deer feeders currently marketed would be suitable for dispensing treated grain or pellets.

Whole corn coated with a marker of metallic glitter was used to deliver invermectin to control ear mites in captive deer (Garris et al. 1991). A corn bait was also used to deliver an anthelmintic to treat fluke-infected deer (Qureshi et al. 1994). Shelled corn and apples were preferred over commercial pelleted feeds and were used to deliver an oral candidate contraceptive to confined deer within a 24.3-km^2 fenced enclosure. The corn was covered with molasses and mixed with alfalfa granules impregnated with DES. Prebaiting trials suggested that deer would consume 0.23–0.46 kg of treated corn per day. Quartered apples containing tablets of DES also were used to deliver the compound to deer (Harder and Peterle 1974). A commercial dairy cattle ration and later a mixture of shelled corn, oats, molasses, and a mineral–vitamin supplement were fed over time and compared with consumption of natural forage (Hubert et al. 1980). In a similar study, Ozoga and Verme (1982) compared seasonal consumption of a supplemental pelleted ration with natural forage and the response of the deer herd over a 5-year period. Seasonal differences in feeding activity (Ozoga and Verme 1970) and consumption of a pelleted ration (Wheaton and Brown 1983) have been reported for captive deer in Michigan and Texas, respectively, further suggesting that the success of administering chemical or biological agents will depend, in part, upon seasonal factors such as the availability of natural forages. Free-ranging deer were offered a pelleted supplement to determine how long they stayed at the feeding site (mean = 12.4 min), how long they fed (mean = 2.6 min), and how much they ate per visit (mean = 0.68 kg) (Zaiglin and DeYoung 1980). Free-ranging deer use and habituation to three supplemental feeds (two pelleted, one corn) were evaluated; consumption increased nearly sevenfold over a 1-year period (Murphy et al. 1992). Confined ad libitum-fed deer consumed an average of 1.6 kg/day of a commercial deer feed (Warren et al. 1984).

White-tailed deer had no preference for protein-energy supplement blocks coated with extracts of cedar fronds, cloves, wintergreen, or a commercially sold attractant (Gamelur™) when compared with untreated blocks (Ullrey et al. 1975). Anderson et al. (1975) field-tested the above supplemental feed blocks by placing five blocks coated with the extracts mentioned above at each of four deer winter yarding sites in Michigan. Despite the feeding stations being placed where deer were active, consumption was noted at only two. Deer appeared to use those blocks located near main deer trails leaving the yarding area. Salt blocks in association with several olfactory lures have been evaluated for use as deer baits. Apple, peanut butter, acorn, and sweet corn extracts were tested, and the first three were found to enhance the effectiveness of salt blocks significantly. Mineral blocks followed by salt blocks and mineral–molasses blocks were preferred in that order. Mineral blocks with apple extract were as attractive to free-ranging deer as mineral blocks presented with mixtures of the above extracts (Mason et al. 1993). Solid baits comprised of mineral blocks with the above-mentioned extracts, and a liquid bait using similar substances (plus water, glycerine, and salt) are described elsewhere in this publication (Mason et al., this volume).

Several investigators have reported on the characteristics of naturally occurring mineral licks and their use by deer (Weeks and Kirkpatrick 1976, Weeks 1978, Jones and Weeks 1985). Most deer frequented licks that were located within or adjacent to their home ranges, but some deer also traveled to licks outside their home range. Artificial licks have been suggested, with salt blocks to be placed 1.5 km apart (Wiles and Weeks 1986). A supplemental mineral supplement was evaluated as a means of improving body mass and increasing antler size (Schultz and Johnson 1992). Such licks or salt blocks may be useful for dispensing agents to free-ranging deer. Rock salt has been used as a bait in live traps for deer (Mattfeld et al. 1972).

Radio-tracked deer were found to use point attractants (e.g., cultivated crops and feeders), but these sources of food did not appear to draw deer from long distances (Licht 1987). Similarly, a simulated test of illegal baiting sought to determine if radio-collared deer were attracted to shelled corn at feeding stations. It was concluded that deer having home ranges that included a feeder used it; however, deer were unlikely to change their movement patterns to visit feeders located outside their home range (Jacobson and Darrow 1992, Darrow 1993).

Orally administered THC has been evaluated as a biomarker in captive deer that were given known doses of the antibiotic (Van Brackle et al. 1994). Large quantities of whole corn overcoated with THC and using Rhoplex-B60A as a sticker were offered as a supplemental feed to free-ranging deer. A high percentage (63.9–90.8 percent) of deer were subsequently found to be marked (Van Brackle 1994). IA given orally to deer will bind to protein and persist in the blood serum and thus appears to be another suitable biomarker for this species (White et al. 1995). Such markers can be used to determine the percentage of local deer populations that ingest treated baits and feeds and also as a means to learn about the movement and harvest patterns of hunter-killed deer (Van Brackle et al. 1994).

Summary

A review of the literature describing baits and bait delivery techniques revealed that considerable information was available for some species (e.g., the red fox in Europe and Canada) but that very little is known about others (e.g., the arctic fox and white-tailed deer). Moreover, literature specifically describing the field delivery of oral contraceptives is limited or nonexistent for nearly all species of interest. Fortunately, much of what is known about delivery of toxicants and vaccines can be adapted for oral contraception. Such information includes bait formulation, knowledge of effective ingredients, bait acceptance rates, use of biomarkers to assess baiting efficacy, selective placement of baits to reduce removal

by incidental species, seasonal and geographic variables associated with baiting, and minimum bait densities needed to treat the desired percent of targeted populations. Furthermore, concepts or field techniques that have been devised for some species can be modified or adapted with judicious care for different animals and situations. For example, the polymer fishmeal bait originally developed in the United States for raccoons was subsequently found to be well accepted and is now widely used for red foxes in Europe. Similarly, a corn, milk, and egg batter-based bait developed for raccoons was accepted by a high percentage of dogs in two rural Mexico studies. However, use of the same bait for different species sometimes may be a poor choice, even for other canids. The raccoon and red fox polymer fishmeal bait was found to be poorly accepted by domestic dogs in the United States, Mexico, and Egypt. Moreover, even the efficacy of biomarkers may differ among species. Tests in captive animals have shown that iodine levels in blood sera induced by iophenoxic acid may persist for different lengths of time (e.g., white-tailed deer *v.* coyote) such that sampling of treated populations must be adjusted accordingly. Differences in masticatory or ingestive behavior among species may also lead to incorrect assumptions; a rabies vaccine container and bait that effectively immunized red foxes has reportedly performed poorly for jackals.

The reproductive physiology and behavior of a species will play an important role in the development of contraceptive delivery systems. For example, dominance and sexual activity of certain individuals within social groups doubtless will have an important influence on when and how contraceptives should be delivered and which sex and age classes should be targeted. Whereas seasonal influences usually have a limited effect on toxicant delivery, this factor may be crucial for most species that have a restricted reproductive season. An understanding of factors such as those mentioned above will help define the approaches needed for contraceptive development. In fact, research on contraceptives (laboratory) and delivery techniques (field) should proceed concurrently, not sequentially, so as to reduce the time required for research and development and because they are mutually dependent upon one another.

Finally, proponents of wildlife contraception should be prepared to respond to both legitimate concerns and the misinformed perceptions of the public and lay and professional organizations that oppose artificially limiting reproduction of species that are hunted, that provide income or economic benefit, or that have been popularized in the media.

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